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Thomas A. Edison Papers

A SELECTIVE MICROFILM EDITION

PART II
(1879–1886)

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A Note on the Sources

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THOMAS A. EDISON PAPERS

A SELECTIVE MICROFILM EDITION
PART II
(1879-1886)

REEL 48

LITIGATION SERIES (LIT-6)

Court Records
Edison Electric Light Co. v. U. S. Electric Lighting Co. [continued]

Edison Electric Light Co. v. United States Electric Lighting Co.

Volume V

Complainant's Rebuttal - Depositions

CIRCUIT COURT OF THE UNITED STATES,

SOUTHERN DISTRICT OF NEW YORK.

IN EQUITY. 3445.

THE EDISON ELECTRIC LIGHT COMPANY,

Complainant,

vs.

THE UNITED STATES ELECTRIC LIGHTING COMPANY,

Defendant.

ON LETTERS PATENT No. 223,898.

VOL. V.

COMPLAINANT'S REBUTTAL.

DEPOSITIONS

AND

EXHIBITS.

EATON & LEWIS,

Complainant's Solicitors.

CLARENCE A. SEWARD,
GROSVENOR LOWREY,
RICHARD N. DYER,

Of Counsel.

C. G. Burgoyne, 146-150 Centre Street, N. Y.

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Depositions.

4084

Depositions—*Continued.*

Depositions—*Continued.*

Complainant's Exhibits—Offered.

Complainant's Exhibits—Offered—*Continued.*

Complainant's Exhibits—Offered—*Continued.*

Complainant's Exhibits—Printed.

Complainant's Exhibits—Printed—*Continued.*

Defendant's Exhibits—Offered.

Notices, Stipulations, Motions, Etc.

Circuit Court of the United States,

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY,
Complainant,

vs.

THE UNITED STATES ELECTRIC LIGHTING COMPANY,
Defendant.

In Equity, 3445.

Take notice that the complainant in the above case will proceed to take testimony in rebuttal therein, under the 67th Rule in Equity, as amended, before S. M. Hitchcock, Esq., a standing Examiner of the said Court on Monday, April 7th, 1890, at 11 o'clock in the forenoon, at the office of C. A. Seward, Esq., No. 29 Nassau street, New York City.

NEW YORK, April 3d, 1890.

RICHARD N. DYER,
Of Counsel for Complainant.

To Messrs. DUNCAN, CURTIS & PAIGE,
Defendant's Solicitors,
120 Broadway, New York City.

Due service of the above notice is hereby acknowledge this 3d day of April, 1890.

DUNCAN, CURTIS & PAGE,
120 Broadway, N. Y.

U. S. CIRCUIT COURT,

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY vs. THE UNITED STATES ELECTRIC LIGHTING COMPANY.	In Equity, 3445.

NEW YORK, April 7th, 1890.

Met pursuant to notice at the office of C. A. Seward, Esq., No. 29 Nassau street, before Samuel M. Hitchcock, Esq., a standing Examiner of the U. S. Circuit Court.

Present—CLARENCE A. SEWARD, ESQ., and RICHARD N. DYER, ESQ., on behalf of the complainant.

SAMUEL A. DUNCAN, ESQ., and LEONARD E. CURTIS, ESQ., on behalf of the defendant.

Complainant's Rebuttal.

In accordance with the stipulation entered into between the counsel on January 28, 1890, and printed at page 1153, Vol. II. Defendant's Record, counsel for complainant give notice to counsel for defendant that the complainant desires to use in this case the depositions in the McKeesport case (and exhibits offered in connection therewith) of Thomas A. Edison, Charles Batchelor, Francis R. Upton, Hugh R. Garden, George W. Sawyer, William Sharp and Walter K. Griffin.

It is stipulated that counsel for complainant may have one week further time in which to give notice of its desire to use any other depositions taken from the McKeesport case under the stipulation of January 28, 1890, before referred to.

Counsel for complainant state that under the stipulations enabling counsel for defendant to introduce depositions and exhibits from the McKeesport case, certain exhibits were introduced as on behalf of complainant in this case which, not being now accessible to complainant or having no material bearing upon this controversy, it is stipulated that such exhibits may be withdrawn, and such exhibits so hereby withdrawn are described in the testimony taken from the McKeesport case as follows:

"Defendant's Exhibit Dynamo Bill," offered on page 488, Vol. II., printed record.

"Defendant's Exhibits Accounts and Jay Lease," offered at page 518, same vol.

"Defendant's Exhibit Man Drawing, Dec. 9th, 1887," offered at page 759, same vol.

"Defendant's Exhibit Sawyer-Man-Keith Record," offered at page 807, same vol.

"Defendant's Exhibit Sawyer-Man-Maxim Record," offered at same page.

"Defendant's Exhibit Sawyer-Man-Weston Record," offered at same page.

"Defendant's Exhibit Sawyer & Man Electric Co.'s Lamp No. 1," offered at page 932, same vol.

"Defendant's Exhibit Sawyer & Man Electric Co.'s Lamp No. 2," offered at page 933, same vol.

"Defendant's Exhibit Experimental Lamp produced by Man," offered at page 941, same vol.

"Defendant's Exhibit Man-Cheever Letter," offered at page 947, same vol.

In view of the fact that the depositions of Edison, Batchelor and Upton, taken from the McKeesport case, were made up in part of depositions given still earlier in an interference proceeding, it is stipulated that the dates when the different portions of the depositions were given may be taken from the interference case and inserted at the proper points in the depositions, subject to corrections by either party at any time before the hearing.

It is further stipulated that the following are correct copies of the depositions of Thomas A. Edison, Charles

Batchelor, Francis R. Upton, Hugh R. Garden, George W. Sawyer, William Sharp and Walter K. Griffin, as they appear in the record of the McKeesport case, with the corrections as to dates before referred to; and subject to the correction of any errors in the aforesaid records which may hereafter be discovered.

EDISON'S McKEESPORT DEPOSITION.

UNITED STATES CIRCUIT COURT,

WESTERN DISTRICT OF PENNSYLVANIA.

CONSOLIDATED ELECTRIC LIGHT COMPANY against McKEESPORT LIGHT COMPANY. } In Equity.

ORANGE, N. J., March 6, 1889.

Met pursuant to adjournment.

Present—Messrs. WALTER K. GRIFFIN and RICHARD N. DYER, for defendant, and THOMAS B. KERR, for complainant; also present Mr. HENRY M. BYLLESBY.

It is stipulated by counsel that the deposition of Thomas A. Edison, the witness present, taken in the interference case between Sawyer & Man, and Thomas A. Edison, may be copied into this record (both direct and cross-examination) as a part of the deposition of Mr. Edison in this case, subject to objections as to the materiality, which may be taken *nunc pro tunc*, at the hearing.

It is also stipulated that any objections found in said deposition, based upon peculiarities of Patent Office practice, such as that the testimony does not conform to the preliminary statement, shall not be considered pertinent in this case. In accordance with said stipulation, and Mr. Edison being duly sworn, the Examiner is requested to copy into the record at this point Mr. Edison's deposition in the interference case.

Edison's Interference Deposition.

NEW YORK, June 11th, 1881.

Pursuant to adjournment the counsel for the respective parties appeared before me at No. 65 Fifth avenue, New York City, at 11 o'clock A. M., GEORGE W. DYER appearing as counsel for Thomas A. Edison, and AMOS BROADNAX as counsel for Sawyer & Man.

By consent the questions and answers were reduced to writing by H. W. Seely, he having first been duly sworn to faithfully and truly record the same.

THOMAS A. EDISON, a witness produced in his own behalf, being duly sworn, testified as follows in answer to questions proposed to him by George W. Dyer, Counsel for Edison:

1 Q. Please state your age and residence and occupation?

A. Age 34; occupation, inventor; residence Menlo Park, N. J.; for the time being living in New York City.

2 Q. Please relate in detail your earliest experiments in the carbonization of paper?

Question objected to unless the experiments were made, or to be used, or with a view of using the paper in electric lighting, and unless the intention was to make the paper in burners for electric lamps.

A. I carbonized paper in the summer of 1876. Such paper was to be used for battery carbons, for non-conductors of heat, and articles were to be made in different shapes and carbonized. A great many articles were so made and carbonized from paper. Sheets of carbonized paper were used for electrical resistance about that time. Strips of carboard or Bristol board, about a quarter of an inch wide and five inches long were placed in gas tubes and carbonized by placing the same in a furnace and heating the tube to a white heat. The strips were packed in the tube oneupon the other and the interstices filled with charcoal powder. Sheets of tissue paper were laid in iron boxes, fifty to a hundred deep, on the top of which was laid a weight of metal so that the carbon would remain straight after being carbonized. Also sheets of thick Bristol board several inches square were carbonized under strain to keep them straight. Some experiments were also made to carbonize small crucibles made out of Bristol board.

Counsel for Sawyer & Man objects to the answer as going to show that the invention was made before the date named in the preliminary statement, in so far as it bears on the making of the carbon-electrode of paper for the electric lamp.

3 Q. How extensive were these experiments, and what persons, if any, had knowledge of them ?

Same objection as to former question.

A. The experiments were quite extensive. My intention was to go into the business of making carbon wire for various purposes, electrical and chemical, for electric lighting and batteries. A company called the American Novelty Company was to handle the goods

in connection with a gentleman name James, who is now dead. Mr. Charles Batchelor, and I believe Mr. E. H. Johnson, saw many of the experiments. Mr. Adams, one of my assistants, now dead, helped me in the experiments. I would mention that we also carbonized wood made up in various shapes, as well as paper.

4 Q. What was the quality of the paper carbon produced at that time in the way you have described ?

Question objected to on the same ground as before.

A. They were very fair carbons after we had got the idea of carbonizing them under strain and pressure.

5 Q. Did you, at that time, determine the quality of these paper carbon strips as to electrical resistance ?

Question objected to on the same ground as before.

A. Yes. We placed them in electrical circuits and worked sounders through them. We also placed one of the crucibles in circuit, and boiled water by the heat engendered by the passage of the current.

6 Q. Did you test the electrical resistance of this carbonized paper as compared with various metals ?

Objected to as impertinent.

A. Yes, sir; we did, as one of the uses of the paper was to make rheostats, and we concluded that the carbon would be suitable for rheostats. The resistances of the various strips were not wide apart from each other. The resistance as compared to metal was very much higher.

7 Q. Please state in detail your next experiments with carbonized paper, and when such experiments were made ?

A. My next experiment with carbonized paper was the use of the same in a telephone, about May or June, 1877. We made telephones in which a great number of sheets of carbonized paper and bristol-board paper were placed between the electrodes in a telephonic circuit, and were agitated by the movements of a diaphragm for the purpose of transmitting articulate speech. In fact, in 1877, we tried every conceivable form of carbon in telephones. About August or September, 1877, strips of carbonized paper were placed in vacuo and brought up to incandescence. Many experiments were tried upon the incandescence of boron, silicon and carbon, in air and vacuo, about that time. My impression is that two gentlemen, Doctor Cordelius Herz, now in Paris, and Stephen D. Field, were witnesses to some of these experiments, whether the boron, silicon, or carbon experiments I cannot say. Also, Mr. Charles Batchelor, Adams, who is dead, and others whom I cannot remember, saw these experiments. I think Herz and Field saw these experiments in September of 1877.

8 Q. Please explain as fully as you can how these last-named experiments in 1877 were conducted?

A. Two rods of brass, sliding in bearings forming the two poles of the battery, had upon their ends small clamps in which different substances could be clamped. In these clamps strips of carbonized paper were placed, about an eighth of an inch wide and two inches long. The paper used for carbonizing was bristol board. The carbon was brought up to incandescence, but quickly oxidized and was destroyed, as it was in the open air. Attempts were made to coat the carbon with powdered glass, so it would melt and run over the carbon and thus preserve it. This did not work. Then experiments were tried on pieces of silicon, which the books stated did not oxidize when in incandescence in the open air. Also upon boron; but these did not succeed well, as they were in very small pieces, and we could not make good contact at the electrodes. Afterwards we tried the experiment in vacuo with a common air pump, but the vacuum that we were able to get was so poor that the carbon oxidized almost as rapidly as it did in the air.

9 Q. Have you any sketch of the construction used for holding the carbonized paper conductor mentioned in your previous answer? If so, produce it. If you have not such sketch, please make one now, to be attached as an exhibit in this case?

A. I think I have the original apparatus, which I believe I can produce, and will do so if possible.

10 Q. In this apparatus referred to, was the carbonized paper strip an incandescent conductor suitable for use in an electric lamp?

> Question objected to unless the strip was afterwards used in an electric lamp, or intended for one at the time.

A. It was used as an incandescent conductor in an electric lamp, but not under proper conditions.

11 Q. When was this experiment made?

A. I think about September, 1877.

12 Q. Why did you not refer to these experiments in your preliminary statement filed in this interference?

> Objected to as incompetent, irrelevant and immaterial.

A. The experiments had, I think, slipped my memory when I made out the preliminary statement.

13 Q. Please state in detail your next experiment in this connection?

A. The next experiments took place, I think, in October or November, 1878. My assistant, Mr. Batchelor, made a great number of paper carbons, fifty or upwards, which consisted of tissue paper and other kinds of paper, coated over their surface with a mixture of lampblack and tar, and then rolled up in the form represented by a knitting needle, and afterwards carbonized by heat. These were included in electrical circuits and brought up to incandescence in vacuo. They were also used in a lamp devised about the same time, which lamp is shown in my patent 224,329, where the light was given by the incandescence of the carbon at the point of contact between the electrodes. The carbon did not last very well in vacuo, and we found it very difficult to clamp it so as to prevent the large current used from producing an arc at the point of contact, but in a form of lamp similar to that shown in Patent 224,329 they gave better results.

14 Q. What degree of use was made of the electric lamp last described?

A. We burnt them for several hours at a time, but the best results were obtained with wood carbons.

15 Q. Are any of those lamps now in existence?

A. I do not think so. I think there were one or two made, and then used for other purposes.

16 Q. Does the drawing of the patent you have just referred to show fairly the construction of the lamp which was made and used at the time named?

A. It does; but we made other forms not shown in the patent. I have represented these in a sketch which I now produce, marked Edison Exhibit 1. In this exhibit figure 1 represents a spring *a*, secured to a pillar B. Upon the extremity of the spring is a clamp c for securing the carbon. The lower extremity of the carbon rested upon iridium pointed prongs *e, d, f*, at the point *x*, the tension of the spring acting to press the carbon slightly against the iridium points. Sometimes the current was passed through the wire *g*, through *a*, thence through the carbon to the points and out by the wire which connected to all three points. At other times the current was passed through the wire *h*, thence through the point *d*, across a portion of the carbon, thence to the point *e* and wire *k*. This latter method is shown better in Figure 4. In this figure the spring *a* is dispensed with and a weight *c* is used to press the carbon against the two iridium pointed electrodes *e, d*. The current passing from *d* to *e* through a portion of the carbon caused it to become incandescent, and as fast as the carbon wore away by oxidation it was fed down by the action of the weight or even by the weight of the carbon itself. In Figure 2 the current passed through the point *h* across the carbon strip, thence down through the point *k*, rendering that portion of the carbon between the two electrodes incandescent. The contact

between the two points was brought about by the weight of the carbon paper. The whole apparatus was placed at an angle. In Figure 2½ is shown about the angel at which the paper was placed, *x* being a limiting stop for the downward passage of the carbon. It was so arranged that if the points *h* and *k* were taken away the paper would fall between the support *g* and limiting stop *x*. Figure 3 shows a modification of the apparatus in Figure 1, a mercury cup being placed on the top of the carbon, in which a platina wire was in contact with the mercury, *a* being the mercury cup, *g* the platina wire. In the Patent No. 224,329 a ball of iridium was used upon the upright metallic portion of the electrode, upon which the contact between the carbon and the iridium took place, as seen in Figure 2 of the drawing of the above-mentioned patent.

17 Q. In the instances named of Patent 224,329, and the modifications just explained by you and shown in your Exhibit No. 1, were the conductors of carbonized paper?

A. Yes, sir. A great many of them were carbonized paper—a few were made out of wood.

18 Q. In all the above-named instances was provision made to keep the electric continuity intact, and prevent the formation of an electric spark?

A. Provision was always made for the passage of a continuous current, the light given was partially due to an arc and partially to electrical incandescence.

19 Q. Can you give any instances of electric lamps of other inventors operating in substantially the same way?

Question objected to as incompetent, impertinent and irrelevant.

A. I believe the Werderman lamp operates in the same manner, also the Joel lamp, now operating in London; and I also believe Mr. Sawyer's late lamps act somewhat on this principle.

20 Q. Are these experiments just described as hav-

ing been made in October or November, 1878, referred to in your preliminary statement ?

Question objected to as incompetent.

A. Yes, sir ; these and other experiments made about the same time.

21 Q. Please relate fully the other experiments referred to in your previous answer ?

A. We, in November or December, 1878, had our vacuum pump placed in order to conduct some experiments on incandescent carbon conductors in vacuo, and we tried a great number of experiments with paper carbons, wood carbons, and carbons made with carbonized broom corn. What we desired at that date, and had concluded as the only possible solution of the subdivision of the electric light, was that the lamps must have a high resistance, and small radiating surface, so as to be capable of being worked in multiple arc commercially, and our calculations showed us that the lamp must have at least 100 ohms resistance to compete successfully with gas, otherwise, if the lamps were of low resistance, the cost of the main conductors would be so great as to render the system uncommercial. What is meant here by a subdivision of the electric light is, that many thousand lamps could all be placed upon a single circuit, and be entirely independent of each other. We, from our previous experiments, knew that we could get the requisite resistance and small radiating service necessary for a commercial use of the light, by means of carbonized paper, or wood ; and, therefore, while working to accomplish this end by means of platinum, we endeavored, by a more perfect vacuum, to obtain incandescent conductors of carbon, which would give us the result. But our experiments in November, as before mentioned with a good pump, wherein we used paper and wood carbons, were not so satisfactory as the experiments we were conducting with platinum conductors. When we made the carbon in such a form as to have a small mass and high resistance to suit our purposes, it would last but several minutes. We then

laid these experiments aside, and went on with platinum, to endeavor to obtain a lamp of high resistance, and small radiating surface. The results of our experiments are shown in patents No. 227,228, 227,227, 227,229. The great point we desired was a lamp of high resistance and small radiating surface, and it did not matter very much whether it was of carbon, or of platinum. The necessity of these features, and the necessity of the single lamp multiple arc system, is more particularly set forth in a British patent No. 2402, dated the 17th of June, 1879, in lines 12 to 37, inclusive, 3d page. Also from line 98, page 1, to line 27, page 2, of U. S. patent 227,229. Also in U. S. Patent 223,898. Nearly the whole of this patent gives information on the subject. Returning to the experiments mentioned at the beginning of this answer on incandescent paper, and other carbons, we found our endeavors blocked in the matter of obtaining incandescent conductors of high resistance and small radiating surface by the fact that we could not make them last for any length of time in the best vacuum obtainable with our air-pump, which was considered a good one. But when, in the course of our attempts to attain the same objects by means of incandescent platinum, we had procured a Sprengel mercury-pump and ascertained that we could get exceedingly high vacuo, it occurred to me that, perhaps, a filament of carbon could be made to stand in the sealed glass vessels which we were using, exhausted to a high vacuum, and in October, 1879, we made lamps of paper carbon and carbons of common sewing thread placed in a receiver made entirely of glass, with the wires sealed therein by fusion, and the whole exhausted by a Sprengel mercury-pump to nearly the one-millionth of an atmosphere, and these filaments of carbon, although excessively fragile, owing to their small mass, had a smaller radiating surface and higher resistance than we had hoped; we had reached the conditions where, notwithstanding the carbons were small in mass and filamentary, they were stable. Sufficiently so to allow of the economical subdivision of the electric light and the possibilities of competing commercially with lighting by gas. It was the new conditions which caused this lamp to be a success, which conditions were high vacuum in a receptacle in which no deterioration or lowering of the vacuum occurred to destroy the carbon. These experiments resulted in the lamp and various modifications and forms, more particularly set forth in my Patent 223,898, and in the application now in interference.

22 Q. Please state what you were doing in the way of experiments upon this subject between November or December, 1878, and October, 1879.

A. I was endeavoring to obtain a lamp of high resistance—for instance, a hundred ohms—with small radiating surface; the former to permit of economical subdivision and the latter to permit of economy in the use of electric power; and I used platinum and platinum-iridium wire during that time to attain this result; all of which are more particularly set forth in the patents which I have heretofore recited. In conducting these experiments we made a great variety of platinum lamps, in which a major portion of the wire was so coiled as to not radiate light, to the end that the lamp might have a high resistance. One of these forms is shown in my Patent 227,229.

23 Q. At what date did you begin to make glass bulbs or shells especially adapted and used for electric incandescent lamps.

A. I think separate lamps, independent of the air-pump, were made either in December, 1878, or January, 1879, except the device used in 1877, which was capable of being detached from the pump and placed in any position, but my impression is that the first vacuum bulb for an incandescent conductor that would hold its vacuum was made in June or July, 1879. This was made entirely of glass, with the conducting wires sealed therein and the vacuum obtained with a Sprengel pump. A platinum conductor was used with these lamps. It might have been as late as August, 1879; I will look over some of my memoranda to-night and refresh my memory on that point.

24 Q. When did you produce electric lamps with incandescent paper carbon conductors in vacuum bulbs, hermetically closed, so as to be a commercially complete lamp, capable of entering into competition with gas lights?

A. I made such a lamp about October 22d, 1879, which had the chareteristics of high resistance, small radiating surface and sufficient stability and economy to allow of competition with gas.

25 Q. What was the extent of your manufacture and use of such lamps thereafter?

A. We commenced immediately to make a number of vacuum pumps and started to manufacture these lamps of paper carbon with the pump we had on hand. During November we made a great number of lamps of this character, perhaps as many as one hundred. These were put up in the laboratory at Menlo Park, and various experiments tried with them, among which was a test of their candle power, economy, resistance, lasting time at various degrees of incandescence. In the latter end of November, 1879, we commenced operations with a view to get our dynamo machines, regulators and wires, in order to make a public exhibition of these lights.

What I mean by a public exhibition is a more general exhibition, as everything that I did in my laboratory for the last three or four years was seen by thousands of persons from all parts of the world. A great many persons visited the laboratory to see the lights in operation in December, 1879, caused by an intimation in one of the daily papers that my electric lights were burning. But on December 21st, 1879, the "New York Herald" published an account of my experiments, a copy of which article is now furnished, marked Edison's Exhibit No. 2.

On December 25th, 1879, I had lighted up my laboratory, my office and two or three houses, situated about a fifth of a mile from the laboratory, and also about twenty street lights. On New Year's Eve, 1879, about three thousand people visited Menlo Park, and thereafter to the present time all my experiments have been public. I have made probably three thousand lamps containing the paper carbon conductor now in interference.

Some time in the Spring of 1880 I lighted up the steamship Columbia of the Oregon Steam Navigation Company with about seventy-five to a hundred lamps containing paper carbons, which continued to light the ship satisfactorily for several months. Exhibitions of the same were made on the steamship Columbia, at Rio Janeiro, Brazil; Valparaiso, Chili; San Francisco, California, and Portland, Oregon. I understand some of the lamps were lighted during the voyage around Cape Horn, and were kept lighted from San Francisco to Portland on the regular trips for several months, and I have recently shipped several hundred lamps to replace the ones broken. Since that time I have tried an enormous number of experiments to cheapen the cost of my lamps, to increase their length of life, and economy and resistance. The nuclei for manufacturing the lamps, established at Menlo Park, in November and December, 1879, have been expanded into two large factories, one situated at Menlo Park and the other at East Newark, N. J. The factory at Menlo Park employs about one hundred hands, turns out about one thousand lamps per day, and has manufactured about sixty thousand lamps. The factory at East Newark is being arranged to manufacture fifty thousand lamps per day.

26 Q. Returing now to the paper carbon incandescent lamps made by you in the winter of 1879-80, what actual use were they subjected to, and what was the extent of their durability as lights; also what was the quantity of light produced by each lamp according to gas standards?

> Objected to as incompetent, irrelevant and immaterial.

A. Each lamp gave about 12 to 16 candles of light. They were put up on chandeliers and run until they were destroyed. Some of them were run all day and

and night, and others by night. A record was kept of the hours each one ran, which record I have here. The lamps are numbered from 142 to 417. Examining this record to refresh my recollection, I am able to state that, for instance, lamp 142 lasted 404 hours; lamp 159 lasted 480 hours; lamp 189 lasted 217 hours; lamp 255, 294 hours; lamp 223, 262 hours; lamp 167, 15 hours; lamp 204, 16 hours; 203, 17½ hours; lamp 155, 280 hours: 201, 280 hours; 164, 322 hours; 172, 259 hours. Looking over the whole record, I should judge the average life was about 300 hours. I remember two lamps, one of which lasted 1,350 hours, and another one 940 hours, cut from the same mold and of the same size and same paper as the lamps I have mentioned by numbers. The numbers I have given occur on the pages of the book consecutively.

> By agreement of counsel, here made, the book of record referred to in the above answer is tendered to counsel for Sawyer & Man for use in cross-examination, and copies of so much of the record as has been testified about by the witness, being pages 1 to 15 inclusive, are attached as exhibits and marked Edison's Exhibit No. 3.

The taking of further testimony was adjourned until Monday, June 13, 1881, at 10 o'clock A. M., by consent, at the same place.

Wm. H. Meadowcroft,
Notary Public,
New York County.

Pursuant to adjournment, this examination was resumed June 13, 1881, at 10 A. M., at No. 65 Fifth avenue, same counsel being present.

The witness, THOMAS A. EDISON, further answers to questions proposed by George W. Dyer, as follows:

27 Q. Since testifying on Saturday, have you made examination among your papers and exhibits at Menlo Park with reference to your early experiments in electric lights in which carbonized paper was used as a conductor; if so, produce what you have found and explain the same?

A. I have made such an examination. I produce an electric lamp in which experiments were made with a paper carbon brought up to incandescence in vacuo. This lamp was used about September or October, 1877. The apparatus originally was one for illustrating Geissler tube action in vacuo. The base of the apparatus fitted over the hole in the platen of the air pump. It was then exhausted and the cock turned to preserve the vacuum in the globe of this lamp. We did not succeed in getting a higher vacuum than 2½ milimeters on the mercury gauge, and we could not make the carbons burn more than a few minutes at a time. Some of the carbons were brought up to brilliant incandescence, and probably gave thirty or forty candles of light. The carbons were brought up to various degrees of incandescence. The carbons were made of sheet paper, of various widths and thickness. I think they were made of Bristol board. They were from three-sixteenths to a sixteenth wide, and probably from eight to fifteen thousandths thick. I believe they were carbonized in tubes made of gas pipe. I cannot remember whether they were prepared at the time or were on hand; we had an immense collection of carbonized paper and wood on hand, which we used in our telephonic experiments, in 1877.

> The lamp referred to in the above answer is put in evidence, and is marked "Edison's Exhibit First Incandescent Lamp."

> Counsel for Sawyer & Man objects to the exhibit upon the ground that it goes to show, and is intended to show, that the invention was made previous to the date alleged in the preliminary statement of Mr. Edison, in this interference, and he objects to all that part of the answer that is intended to show or goes to prove that the invention was made previous to the time alleged in such preliminary statement, and gives notice that upon the hearing of this interference he will move to strike out the exhibit and all that part of the answer objected to.

28 Q. Can you explain now why you did not refer to this exhibit in your preliminary statement?

> Objected to as incompetent, immaterial and irrelevant. Notice of motion to strike out at the hearing.

A. I had forgotten about the experiments. I had forgotten that I had the exhibit, and it only came to my recollection Saturday, in conversation with my assistant, Mr. Batchelor. The results were probably not sufficiently satisfactory to impress it upon my mind. I try so many thousand experiments in all branches of physics that I sometimes forget some of them. The preliminary statement was made at a time when I was under great strain and crowded with people at my laboratory.

> Answer objected to on the same ground stated in the objection to the question. Notice of motion to strike out at the hearing.

29 Q. If you have any other exhibits found by you at Menlo Park on your late search, please produce such with full explanations?

> Question objected to upon the ground that it is incompetent, unless it is intended to call out evidence to show that the invention was made

subsequent to the date stated in the preliminary statement.

A. I present an exhibit which serves to refresh my memory regarding the experiments tried on electric light in 1877. The exhibit is dated November 1st, 1877, witnessed by Charles Batchelor, myself and John Kruesi, and I know the signatures to be their handwriting. In this exhibit is shown lamps giving light by the incandescence of boron, silicon and other substances included in the electric circuit, such lamps being arranged in series and in multiple arc. The experiments with carbonized paper in vacuum were made previous to the date of the exhibit of November 1st, 1877.

Answer objected to as intended to show that the invention in controversy was made previous to the date given in the preliminary statement of Mr. Edison.

Notice of motion to strike it out at the hearing.

Paper referred to put in evidence and marked Edison's Exhibit No. 4.

Exhibit objected to on the grounds stated in last objection, and notice of motion to strike out repeated.

I now produce another paper, dated December 3d, 1877, which serves, like Exhibit No. 4, to refresh my memory regarding experiments with the paper carbon. This paper is witnessed by myself, Charles Batchelor and John Kruesi, and I know the signature to be their handwriting. It refreshes my memory as to the fact that we were trying to subdivide the electric light into a small number of burners, where the circuit was closed by solid conductors, and the reason why experiments were conducted with boron and silicon was because they were not subject to oxidation like carbon, which we had previously tried, and which did not last as long at a white incandescence as pieces of graphitoidal silicon, forming part of the electric circuit, and rendered incandescent by the passage of the current. The results of the carbon experiments, and also of the boron and silicon experiments, were not considered sufficiently satisfactory, when looked at in the commercial sense, to continue them at that time, and they were laid aside.

The paper referred to in the above answer put in testimony and marked "Edison's Exhibit No. 5".

Paper Exhibit objected to as impertinent and irrelevant, and as intended to show that the invention was made previous to the date mentioned in the preliminary statement.

Notice of motion to strike it out at the hearing.

30 Q. Please state whether or not the paper Exhibits No. 4 and No. 5. were written at the dates given upon each of them?

A. Yes, sir; they were.

31 Q. State whether or not your memory is distinct as to the fact that the experiments with boron and silicon, mentioned in these exhibits, were made after your experiments with carbonized paper conductors, and after the employment of such conductors in the lamp marked "Edison's Exhibit First Incandescent Lamp?"

Same objection as before, and same motion.

A. I am certain it was before; because we used boron to get rid of oxidation, to which the carbon was very sensitive.

32 Q. If you have any other exhibits relative to the matter in question, found in your late search at Menlo, please produce the same with explanations?

A. I present a lamp, which is one of my well-known carbon horseshoe lamps, made, I think, some time in December, 1879, and is one of the same kind and character as those made in October, 1879. This lamp is illustrated in the "New York Herald" of December 21st, 1879, heretofore put in evidence.

33 Q. State, if you please, in that connection, whether or not this lamp was actually put in circuit, when and where burned, stating the length of time, and the amount of light given by it?

A. I find that its number is 235, and on referring to my note-book I find that the lamp either burnt seventy hours and eighteen minutes or 250 hours and forty minutes, as the record is obscure. It gave a light of probably from twelve to sixteen candles. It is one among a hundred that were burning at the same time. One lamp, which I have previously mentioned, made in the same way and in the same manner of carbonized paper, lasted over 1,[illegible]00 hours, and I believe that the lamps of this character, made in the regular way, had an average life of about 300 hours, which was sufficient to render them a commercial success in competing with lighting by gas. Had they but lasted an hour, or if the average life of a great number of these lamps were only a few hours, they would not have been a commercial success, and the results would have been of no benefit to the public.

But these lamps, in addition to the fact that they lasted for a long time, had other characteristic, without which, even with a long life, they would not have been available for competing with gas. These important characteristics were that they were of high resistance, of small radiating surface, and hence economical, for the reason that smaller conducting wires could be used for conveying the current, as owing to the high resistance of the lamps weak currents were only necessary and sufficient energy to produce the result was forced through the wire and lamps by increasing the electric pressure or electro-motive force. If lamps of low resistance were placed in multiple arc in a single circuit, the aggregate resistance of all the lamps would be very low, and conductors of correspondingly large dimensions would have to be used, otherwise a great loss of current in the form of heat would take place on the conductor. Hence, if the resistance of each lamp was made, say one hundred times greater, then the conductors could have a

hundred times less area, and the losses would be the same in both cases. With small radiating surface less energy is required to produce a candle power than on a larger surface. Again, economy is attained from the fact that these filaments of carbon, being small in mass, do not conduct heat any better than they do electricity, and therefore very little heat is conducted from the glowing incandescent conductor to the clamps and supports for the same. Hence no special appliances are essential to get rid of the heat of conduction, as are employed in the type of lamps experimented upon by Mr. Sawyer. Again, high vacuo render the carbon horseshoe practically stable and at the same time result in great economy in the use of electricity, as practically all the energy is lost by radiation, and none by conduction. My experiments have shown that if the carbon horseshoe is placed in an atmosphere of nitrogen at the atmospheric pressure, which is the method adopted by Mr. Sawyer in his lamp experiments, it requires nearly twice as much electricity to bring the horseshoe up to the same candle power as it does when the horseshoe is in a high vacuum. As in the former case, heat is lost by conduction through the gas, which serves to carry it to the inclosing globe, from which it radiates invisibly. Hence the lamp is, I believe, the first one ever produced that was commercially available for competition with lighting by gas, and of great public utility.

This lamp, No. 235, was made at my own laboratory at Menlo Park, some time in December, 1879, was put up in a street lamp at the top of the stairs in front of the depot at Menlo Park, a fifth of a mile from the laboratory, and there burned until destroyed. I think it was made a few days before it was put up. According to its record I find it had burned forty hours, previous to January 3d, 1880. It was seen along with about a hundred others like it, by at least twenty-five thousand people, in December and January. At least that is my impression.

All that part of the answer after the ninth line (fourth printed line) is objected to as irresponsive and a mere lecture on the best proportion for making a lamp and burner, in Mr. Edison's opinion.

The lamp referred to in the previous answer is put in evidence and marked "Edison's Commercial Indescent Electric Lamp."

34 Q. Please point out the peculiarities of construction which make this lamp of practical value as compared with other incandescent lamps, and particularly those produced in accordance with the inventions of Sawyer & Man?

A. I have already stated that in my previous answer, to which I refer as an answer to this question.

35 Q. Please state whether or not this exhibit is one of the class of lamps of which you have testified previously that about 3,000 were made, and if there were any differences in construction in any of the 3,000 lamps, please state what such differences were?

A. They were the same, except, perhaps, in the shape of the clamps for holding the carbon and in the form and method of clamping the paper horseshoe carbon to the wires that were passed through and were sealed into the glass.

36 Q. Calling your attention to this exhibit, please describe fully the bulb or globe, stating when and where it was made and by whom, and the advantages connected with its form and size?

A. The lamp was made some time in December, 1879, I think by a person named Boehm, who was employed as a glassblower at my laboraory at Menlo Park. The great advantage of this form and kind of inclosing chamber is that, unlike all previous attempts made for lighting by the incandescence of carbon, the incandescent conductor is placed in a chamber made entirely of glass, the wires forming the leading-in conductors passed from the exterior to the interior of the chamber and sealed by fusion of the glass where they pass through it. Hence these glass chambers when exhausted to high vacuum preserved the exhaustion constant, and thus provide the all-essential condition of high economy and length of life of the thin filament of carbon which it is essential to use to attain high resistance, to permit of the economical subdivision of the electric light. All attempts, I believe, heretofore have failed to preserve the vacuum, where a vacuum is used, and thus preserve the carbon, for the reason that the chamber was not composed entirely of glass, but of glass and metals and materials, between the glass and which there was a difference in coefficient of expansion, which at times admitted the air; hence most inventors have used a supposably inert gas in the chamber at atmospheric pressure, and the leading-in wires have not been passed through the glass and fused therein, which is an essential feature. The form and size of this lamp are very convenient, as it is small, light, portable, durable and admits of radiating the light in all directions, so that practically none is lost. Its size is such that it contains very little air, hence is quickly and economically exhausted of the same in the process of manufacture, and the whole lamp is so light as to be used on chandeliers now used for gas in great numbers.

37 Q. Referring to the same lamp, please describe the leading-in wires and the incandescent conductor, and state the advantages connected with the form and size of the same.

Objected to as immaterial, impertinent, and not bearing upon any issue in controversy.

A. The leading-in wires to within a quarter of an inch of the glass are formed of copper. To these copper wires are secured, by soldering, platinum wires, which are passed through and are fused in the glass. Upon the extremity of these wires, within the chamber, are clamps which serve to clamp the broadened ends of the filament of carbonized paper. This broadened end is essential to permit of a proper clamping and electrical contest, as the increased conductivity of the broadened end to the electric current prevents it from becoming incandescent. Hence, little arcs and bad contacts at the point of clamping which would tend to destroy the lamp do not take place. If the filament of carbon was of the same size all over, so that the portion clamped was no larger than the portion which was incandescent, the lamps of this character would be rapidly destroyed by the formation of small arcs at the point of clamping, which, throwing out the vapor of carbon and platinum within the vacuum, would permit of the formation of a large arc between the two leading-in wires, and the lamp would be instantly destroyed. The paper horseshoe being of small radiating surface and small in mass is very flexible, and after the passage of the electric current very tough. Hence the lamps may be handled, practically, with impunity as far as breaking the carbon horseshoe is concerned. In fact, after the current has passed through the horseshoe the two broadened ends may be taken in the fingers and pulled out nearly straight without breaking. The advantages of the horseshoe shape are that it permits of the expansion and contraction of the carbon freely without injuring it, and also permits of nearly all the light being utilized—in fact, nearly the maximum amount. The necessity of using platinum to seal in glass is that of all metals its sufficient of expansion is nearest glass, and hence the glass and platinum will expand and contract together under differences of temperature and thus prevent leakage of air or cracking of the glass chamber.

Same objection to answer as to question.

38 Q. Please state how the carbon conductor in this lamp and those like it was made, and where?

A. The carbon conductor was made at my laboratory at Menlo Park either in October, November or December, 1879, in the manner and of the material described in my application, now in interference.

39 Q. Please state how you exhausted the air from this lamp and others made like it?

A. We exhausted the air by means of a double glass pump, one part of the pump being known as Geissler pump and the other as a Sprengel pump, in which mercury was used in the well-known manner. The apparatus is shown on page 99 of my note book No. 85 (a copy of which sketch is produced and put in evidence and marked Edison's Exhibit No. 6).

Exhibit objected to as being secondary evidence, being an alleged copy and not the original referred to by the witness, and the copy not being produced.

Counsel for Edison states that the sketch referred to is one of the pages of a very valuable book of original records, which book is now tendered to the counsel for Sawyer & Man for inspection, and that a tracing copy will be furnished as soon as it can be made and before the examination of this witness is closed.

40 Q. To what extent was exhaustion produced by the apparatus described?

A. I think the exhaustions were carried beyond the millionth of an atmosphere. We had on this apparatus a McLeod gauge to measure the degree of exhaustion. In the notes which accompany this sketch it is stated that a vacuum was obtained where the jumb spark from an induction coil jumped five (5) inches in air rather than pass across between electrodes a quarter (¼) of an inch apart in vacuum. This denotes exceedingly high vacua, exceeding the millionth of an atmosphere.

41 Q. When was the sketch referred to made?

A. It is dated October 2d, 1879, and witnessed by S. D. Mott and myself. The drawing was made by Mr. Mott, and it was I think made on the day of date. The notes are in the handwriting of Mr. Upton. I think the notes were made about the same time.

42 Q. Please read from these notes whatever refers to the construction and mode of operation of the vacuum apparatus shown in the sketch?

A. I will furnish a copy of the notes referred to, taken fro... the book, which copy will be marked Edison's Exhibit No. 7.

> Mr. Broadnax objects to the notes, because it appears that they were not made by the witness himself or in his presence.

43 Q. Whose property is this book, and under whose direction and by whom were the entries made in it?

A. The book belongs to myself. It is one of about two hundred or more books in which my experiments in electric lighting are recorded. The entries relating to this exhibit were made by Francis Upton, my assistant, under a general direction from me. The sketch itself was made by Mr. Mott, another one of my assistants.

44 Q. Please describe briefly the manner in which the apparatus shown in the sketch referred to operates in exhausting air from lamps, and if necessary to make the sketch more clear, put additional letters of reference on the parts?

A. The bottle at the top of the pump is the mercury reservoir, leading from which is a rubber tube through which the mercury passed up to the first glass tube on the left hand side of the pump board. The mercury then passed into the air-trap G, then around the bent tube to the contraction F, through a small tube within a bulb, thence dropping down the second tube on the right to D. These drops of mercury, in dropping, acted as pistons, between which the air was confined after the manner employed by Sprengel. E X is the McLeod guage for measuring the degree of exhaustion. A bottle on the left lower corner, containing mercury was connected to the McLeod guage by a rubber tube. When this bottle was lifted the mercury passed up in the round bulb of the gauge and forced what residual air there was up into a tube with a capillary base and with a paper scale behind it. The two tubes on the right of the pump stand form the well-known Geissler pump. The mercury bottle at the lower end on the right was connected to the second glass tube on the right of the pump board by a flexible rubber tube. A stop-cock B being turned so that no mercury could enter the main vacuum apparatus, the bottle was lifted and the mercury ran into the chamber in the upper part of the tube, filled it, and forced what air there was in it over into and down the first tube on the right to the trap D, and thence to the atmosphere. The mercury bottle was then lowered, and the mercury ran out of the chamber, leaving a vacuous space. The cock B was then turned so that the chamber formed part of the general vacuous space of the pump. The bulbs on the right hand corner at the top were the lamps, which were all sealed by fusion with each other, and then to a tube provided with a ground glass stopper fitting into the vacuum apparatus. A stop-cock on the right near the top served to disconnect the pump from the bulbs or lamps when they were properly exhausted, so they could be sealed off and others put on without losing the vacuum in the pump entirely. The two bulbs on the top and above letters B and C contained phosphoric anhydride, to remove water vapor from the air, and gold leaf, to absorb mercury vapors. Above these is the Geissler spark gauge with the two electrodes. The major portion of the air was taken out by the Geissler pump and the rest of the exhaustion was carried on by the Sprengel pump..

45 Q. In addition to means for making lamps completely, like that shown in Exhibit Edison's Commercial Electric Lamp, and means for exhausting the air completely from such lamps, what else had you done in the latter part of 1879 towards a perfect operative system of electric lighting by incandescence?

A. I had been devising a complete system for the general distribution of electricity, so as to compete with gas. I had dynamo machines, a station regulator for keeping the pressure constant throughout the system, meters for measuring the amount of current consumed by each customer, street mains for distributing the electricity, sockets for holding the lamps and chandelier appliances, electro-motors for utilizing electricity for power on the light wires, vacuum pumps and devices for the manufacture of electric lamps, carbonizing furnaces, and molds and appliances therefor, and in fact a complete system of electric lighting by incandescence, upon the plan of general distribution over large areas. About the middle of December, the whole system was started and publicly exhibited to many thousand people. Several houses were lighted, besides my laboratory, and twenty street lamps were also lighted. What has been done since that date has been towards means and methods of manufacture, cheapening the processes of manufacture, and establishing factories. In the latter end of December, or in the early part of January, I accepted the proposition of Mr. Villard to light up the steamship "Columbia." I immediately went to work preparing to do so. The apparatus was finished and placed on board a few days after she came out of the ship yard, which was, I think, in May or June, 1880.

46 Q. What was the resistance of the lamps made by you in the latter part of 1879?

A. Some of them were as high as 1,000 ohms, but the average resistance of the paper carbon was about 100 ohms when hot.

47 Q. In your late search at Menlo did you find paper or model exhibits of experiments of 1878, which you are now ready to offer?

A. I did not find any apparatus that I was sure was used in 1878 with the paper carbons, but I have a man searching for them. My practice is that when I make apparatus to try an experiment I keep making changes on this apparatus to try other experiments, many of which have nothing in common with the purpose for which the instrument was first devised. I conduct such a great number of experiments that I could not afford to keep the original apparatus if it was required to try another experiment, even with a matter entirely dissimilar as to its object.

Counsel for Edison gives notice that, if at any time during the examination or cross-examination of his witness any exhibits of experiments of 1878 are found, he will put the same in evidence.

48 Q. In all the instances of carbonization of paper given by you in this testimony was there any other treatment of the paper besides simple carbonization?

A. In the lights made of paper horseshoes, of which there were about a hundred burning at a time, and which I have spoken of as being exhibited to the public, the paper carbons were not treated. Some lamps were made in December, 1879, to see what effect treatment would have but only a few were made. In the experiments in 1877 with a paper carbon no treatment of the carbon with any other substance was made, except the incidental effect of the grease used in the lamp being decomposed and depositing carbon on the incandescent conductor in the Exhibit First Incandescent Lamp. This was not an intentional treatment. The carbons made in 1878 were generally composed of paper having its surface treated with lampblack and tar. I believe a few of the carbons made in 1878 were soaked after carbonization in tar, and recarbonized.

49 Q. I call your attention to the printed record of the testimony of A. Man, near the bottom of page 7, where he says: "We use principally ordinary blotting paper." Have you had any experience in the carbonization of ordinary blotting paper, and if so, with what result?

A. Yes, sir. I have carbonized blotting paper. It makes a loose, non-coherent, friable carbon. Some kinds of blotting paper separate in carbonizing into two or three layers. When a current is passed through it, little arcs occur throughout the carbon, due to the loose contact of one fibre with another. I have made incandescent carbon conductors out of it, but they are not satisfactory.

50 Q. I further call your attention to another paragraph upon the same page of Mr. Man's testimony, at the bottom of the page, where he speaks of "rubbing down and working out by hand the carbon," and ask if

you have ever had any experience in this kind of manipulation of paper carbon?

A. I do not conceive how it is possible to rub down a paper carbon made out of blotting paper, without it is very large, such as an eighth (⅛) of an inch square, and then I judge it would be exceedingly difficult. I never did this, nor did I ever see anyone do it. If the carbon was anything like the flexible filament as shown in my flexible commercial electric lamp, I should say it is impossible. Further, I do not see the necessity of it, as any thickness of paper could have been used, and any desired shape could have been obtained from the paper in the first instance. It is not an easy matter to rub down blotting paper before it is carbonized.

The taking of further testimony herein was adjourned by consent to Tuesday, June 14, 1881, at same place.

WM. H. MEADOWCROFT,
Notary Public,
N. Y. Co.

Pursuant to adjournment, this examination was resumed June 14, 1881, at 10 A. M., at No. 65 Fifth avenue, the same counsel being present.

The witness, THOMAS A. EDISON, further answers to questions proposed by George W. Dyer, as follows:

51 Q. I call your attention further in the testimony of Albon Man, answers to the 4th and 18th questions, and ask if paper carbonized electrically as described can afterwards be made incandescent?

A. I have tried many experiments on the carbonization of paper, both by the passage of the current through a filament with plumbago on its surface and also by the passage of current through a platinum conductor on which the paper rested, and always found that the decomposition of the cellulose and water of the paper produced sufficient oxygen to consume all the

carbon of the paper, and the result was that nothing was left but the natural ash. These experiments were conducted in vacuo. I do not see how it is possible to produce a carbon which could be used in a lamp by simple carbonization of the paper by the heat produced by the passage of the electric current in an atmosphere of nitrogen, hydrogen, or air.

52 Q. Referring to the 57th and 57½ questions and answer of Albon Man, what would become of a Florence flask filled with gas as described and subjected to currents of electricity?

A. I have placed illuminating gas in flasks similar to a Florence flask and in which there was an incandescing conductor of carbon, and on heating the same to a high incandescence the globes exploded, due to the enormous expansion of the gas and decomposition of the same.

53 Q. Referring to answer to question 61 in the testimony of Albon Man, what comment, if any, have you to make on the statement that the oxygen of the salts would consume the paper?

A. I do not see how any oxygen salt would cause the paper to become a conductor. I do not believe there is a dry oxygen salt that is a conductor of electricity sufficient to allow a current to pass through a strip of paper impregnated with it. If it was moistened to permit of conductivity the moisture would be evaporated before carbonization, because the water could not exist at a high temperature sufficient to carbonize. And if the water was dissipated the oxygen salt would not be a conductor.

54 Q. Referring to the answer to Q. 67 of Albon Man, what comment, if any, have you to make upon that?

A. I do not see that the treating of the paper carbon by a hydro-carbon gas, to deposit hard carbon, improves the paper carbon. If the paper carbon was originally bad it will always remain so. If it is coated by deposition of hard carbon the light is radiated then from a hard carbon and not from a paper carbon. If the paper carbon is to have a deposit of this hard carbon placed over it, and within it, it doesn't matter whether the paper carbon is good, bad or indifferent, or is any other form of carbon, or even a metal. The incandescing conductor of the lamp becomes really and truly a hard carbon conductor, as the major portion of the current passes through the hard carbon and all the light is radiated from it. If a paper carbon is dipped in different hydro-carbons several times and recarbonized each time a deposit of hard carbon takes place on the surface as well as within the paper. The use of a hydro-carbon for depositing hard carbon by electrical incandescence is only a method for rendering a useless carbon available in an electric lamp.

It is, in fact, an evidence of the imperfection of the carbon paper.

> Answer objected to as being mere argument and not any statement of facts responsive to the question, the answer being mere criticism.

55 Q. In the foregoing answer have you expressed an opinion simply as an expert, or spoken from knowledge derived from experiments made by yourself?

A. Derived from experiments made by myself.

56 Q. Referring to the answer of Albon Man to the 80th question, what effect would the glue mentioned in the answer have in the employment of the paper carbon for incandescence in a lamp?

A. The effect would be that when the same was placed in the lamp it would be carbonized, and a great amount of smoke would come out and obscure the globe. This is from my actual knowledge.

57 Q. Calling your attention to the answers of Albon Man to questions 83, 84 and 85, I ask what would be the result of carbonizing the paper described, in the way described, and working it down after carbonization as described?

A. The result of using several thicknesses of blotting paper pressed together would be that when they were carbonized they would all separate, each would be contorted in a different manner, and I do not believe they could be used or worked down, as stated by Mr. Man. I

know this from my own experience. Could they have been kept together, which was impossible according to the method of carbonizing described by Mr. Man, they might possibly have been worked down by emory paper, providing they were large enough, but from the sizes given by Mr. Man in another part of his testimony, I do not see how it is possible. It would seem that the proper method would have been to cut the paper in the form desired and then carbonize it, instead of cutting it in a form not desired and then working it down after it was carbonized.

That is a method of manufacturing by machinery or appliances.

58 Q. I call your attention to the sketch Sawyer's Exhibit No. 3, Albon Man, and ask if it would be possible for the spring clamp there shown to clamp the ends of the carbonized paper described?

A. I do not see how a practical lamp could be made with such clamps. Mr. Man has testified that the width of the carbon was from $\frac{1}{12}$ to $\frac{1}{20}$ of an inch, and as these carbons rest upon the plate of platinum *c* in the sketch, the length of the spring portion of the clamps would only be from $\frac{1}{12}$ to $\frac{1}{20}$ of an inch. This is manifestly absurd.

59 Q. I call your attention to the answer of Wm. E. Sawyer to the sixth question, and ask if such a carbon was used as an incandescent conductor in an electric light, what would be the source of light in the incandescent conductor?

A. The source of light would be a hard gas carbon and not the paper carbon.

60 Q. I call your attention to the answer of Wm. E. Sawyer to the eighteenth question, and to what is there stated about candle-power, duration of burners and fracture, and ask you to state from your own knowledge the results that would follow from the various conditions named in the answer.

A. The life of the lamp would depend upon the unit incandescence. Referring to Mr. Sawyer's answer to cross-question fifty-three, I have made a calculation as to the radiating surfaces of the carbon, whose size has been given by Mr. Man, and as to that of the carbon in my Exhibit marked "Edison's Commercial Incandescent Lamp," and find that the candle power per unit surface is greater in my lamp at sixteen candles than in the lamp described by Mr. Man, giving thirty candles. In giving candle-powers, the total radiating surface is the main factor which should be always given.

Had I the same radiating surface in my lamp, it would have given about thirty candles, and lasted just as long, theoretically. Practically, it would last longer, as the smaller and lighter the carbon the more difficult it is to manufacture it so perfect. To show how absurd it is to give candle-power without the radiating surface, one might make a lamp that would give twenty-five candles when only brought up to a yellow heat. From my experience I should judge that the carbon made of the material and in the manner specified and and used under the conditions specified, would last on an average about as long as was stated by Mr. Sawyer in his communication to the New York papers, about December 22d or 23d, 1879, that is, they would not last more than a few minutes. In fact, Mr. Sawyer stated in a communication to the "N. Y. Sun," December 22d, 1879, which is now before me, and dated from 78 Walker street, December 21st, that a carbonized paper lamp would not last three hours, and also stated that in practice it would not last twenty minutes in a perfect vacuum. Now, as Mr. Sawyer did not get anywhere near a perfect vacuum, and yet from his experiments predicated the statement that even in a perfect vacuum they would not last twenty minutes, the results obtained by Messrs. Sawyer & Man can be readily surmised. That were undoubtedly very dismal failures.

The article from the "N. Y. Sun" of December 22d, 1879, referred to in the foregoing answer, is put in testimony and marked Edison's Exhibit No. 8.

The exhibit is objected to upon the ground that there is no evidence that it was published in the "N. Y. Sun," or that Mr. Sawyer wrote it.

All reference made to the article in the witness' answer is objected to on the same ground. And upon the further ground that the article is not evidenced in any sense.

61 Q. Refer, if you please, to the descriptions given by the witnesses for Sawyer & Man, and the sketches and drawings referred to by them in the printed record of Sawyer & Man's testimony, and taking into view the incandescent conductors employed, and the heat radiators employed, and the other parts of the lamp, would such a lamp, in your opinion, be a practical lamp or not, giving reasons for whatever opinion you may express?

A. No, sir, it would not be a practical lamp. The testimony of even Messrs. Sawyer & Man, and the statements of Mr. Sawyer and his witnesses prove that it is not a practical lamp. No lamp has ever yet been devised up to the present date that was practical which had an inclosing chamber partially made of a cup of metal and secured to the glass by cements. In fact, Mr. Sawyer states the same in his patents, and shows many devices to obviate this defect. A sufficiently high vacuum cannot be obtained in chambers of this character to prevent oxidation and electric convection of the carbon. When the globe is filled with nitrogen, the atmospheric gases will still pass in, in the manner described by Graham in his experiments upon the transpiration and diffusion of gases. A great many inventors, including Messrs. Sawyer & Man, place their carbons in an atmosphere of nitrogen, on the theory that nitrogen is inert towards carbon. It is well known that carbon at high incandescence combines with nitrogen to form cyanogen, and the cyanides due to ash of the carbon. My assistant, Dr. Moses, has obtained a chemical reaction for cyanogen compounds, formed by electrical incandescence of carbon in an atmosphere of nitrogen. To obviate the defects of an imperfectly sealed chamber, Messrs. Sawyer & Man introduce nitrogen gas, upon the theory that if the atmosphere in the globe is at the same atmospheric pressure as the exterior atmosphere there will be no tendency of the oxygen of the exterior atmosphere to pass within the globe, and that nitrogen is inert towards carbon. Both of these theories are wrong.

Another reason why the lamp would not be a practical lamp is that the carbon in the lamp which Mr. Sawyer testifies was the perfected lamp is not provided with thickened ends, whereby the incandescence of the carbon is reduced ; hence, it can only have its incandescence due to the passage of the current reduced by conduction of the heat away from the carbon at the point of contact. The carrying capacity and heat conductivity of these clamps are so small, compared to the size of the carbon and the incandescence which it is necessary to bring the carbon up to, to give, say twenty candles, that the carbon at the point of contact would be partially incandescent, as the heat could not be conducted away fast enough, and a bad contact between the carbon and the clamps would necessarily follow, accompanied by small arcs, which would gradually increase and ultimately destroy the contact. The amount of energy lost by conduction would be far greater than that lost in the form of useful light. My assertion in this respect about the conduction of heat are verified by the construction of the lamp itself, where special means are employed in the way of radiators whereby the heat of conduction may be radiated so that the lamp will not get too hot. This energy is of course useless for light-giving purposes, and consumes nearly as much electricity as is required to produce a light of twenty candles in the carbon. The great heat also produces great differences of temperature in the inclosing case, and therefore difference in the expansion of portions of the case, which causes leakage from the atmosphere into the case. Another thing is, that if when the lamp is cold the gases within it are at the same pressure as that of the atmosphere, this result will be changed when the lamp is lighted. The gas within the globe becomes expanded and there is a different pressure, the tendency of which, if there is leakage, is to force the gas out of the lamp until the pressures are constant. If

this takes place and the lamp is allowed to cool, then the atmospheric pressure will be the highest and there will be a tendency for the atmosphere to pass into the globe. For these and other reasons which could be mentioned the lamp which Mr. Sawyer calls his perfected lamp is, in my view, entirely impractical, commercially, scientifically, or otherwise.

I have previously stated the reasons why it would not be practical commercially in a previous part of my testimony. Its resistance would be too low to admit of practical subdivision, on account of the great investment required for copper conductors.. It would not be sufficiently economical on account of the energy lost by conduction and by convection through the residual gas.

Counsel for Edison gives notice that, reserving the right to put in certain patents, the data of which he will procure, and exhibits of experiments in 1878, for which search is now being made during the course of this examination, he here rests his examination of Mr. Edison, and offers him for cross-examination. Counsel for Sawyer & Man gives notice that his cross-examination of the witness will be *de bene esse* as to all that part of the witness' testimony that is intended to show or goes to show that he made the invention previous to the date alleged in his preliminary statement, and that he does not intend that his cross-examination shall be construed as a waiver of any objection he may have entered of record, and that he will object and move to strike out, either before or at the hearing of the interference, any re-examination of the witness, or any testimony or exhibit put in that does not refer to new matter brought out in the cross-examination.

Cross-examination by Amos Broadnax, Esq., Counsel for Sawyer & Man :

62 x-Q. In answer to question 1 of your examination-

in-chief, you say you are an inventor by occupation. Please state what inventions you were working on in the summer of 1876?

A. I was working on telephones, accoustic electrical transmission, electric pens, multiple copying apparatus, duplicating ink, galvanic batteries, sextuplex telegraphs, duplex telegraph, manufacture of carbon articles, and other things which I cannot now remember.

63 x-Q. How much of your time during the summer of 1876, were you engaged in working on telephones? I mean what time in the summer did you begin the work on telephones, and what time did you leave off?

A. I commenced to work on telephones in 1875. I have never left off since that date.

64 x-Q. How much of your time was given to telephones during the summer of 1876?

A. It would be a difficult matter to divide my time up between all the things I was working on. I should say one-tenth of my time was given to speaking telephones.

65 x-Q. Were you working in the summer of 1876 at one and the same time, or during the same period of time, upon all the inventions you mentioned in answer to 62 x-Q.?

A. Yes, sir; I think I was.

66 x-Q. Was there any exigency in the development of either of the inventions referred to by you that moved you to carbonize paper?

A. I have stated that one of the things I was working on was the carbonization of paper to form different articles. One of my assistants, Mr. Johnson, had formed, or was about to form, a company called the American Novelty Company, whose purpose was to work off some of the small inventions which I was making. The manufacture of a great many articles from carbon was one of these inventions. Among other things was an electrical sheepshearing machine, an electrical drill, an electrical engraving machine, ribbon mucilage and other inventions which I cannot now remember. They were small things. I think he had a list of about twenty.

67 x-Q. What articles did you propose to manufacture of carbonized paper?

A. Battery carbons, strips of carbon for electrical resistances, dishes for use in making chemical reactions and tissue paper as a non-conducting packing.

68 x-Q. How many of these articles did you make?

A. We made four or five crucibles, a great many flat sheets and a half a pound to a pound of carbonized tissue paper.

69 x-Q. How long did you continue to work at your experiments in the manufacture of articles of carbonized paper in the summer of 1876?

A. I should say we tried experiments on an off for perhaps two months.

70 x-Q. Please to state when you began your experiments and when you discontinued them, as near as you can recollect?

A. As near as I can recollect, it was in the summer of 1876.

71 x-Q. Can't you state at what time in the summer of 1876 you commenced your experiments and at what time you discontinued them?

A. I should judge that it was about June or July, 1876.

72 x-Q. State, if you please, when it was that you next took up the subject of carbonizing paper?

A. I think about January, 1877.

73 x-Q. What circumstances moved you to return to the carbonization of paper in January, 1877?

A. Using it in a telephone.

74 x-Q. How long did you continue to use carbonized paper in your telephone?

A. I think I used it as late as January or February, 1878, perhaps later. All my exhibits are in the telephone interferences and I have nothing here to refresh my memory.

75 x-Q. For what other purpose did you use carbonized paper in January, 1877?

A. I used it for resistances.

76 x-Q. After January, 1877, did you discontinue the carbonization of paper?

A. No, sir; I think we carbonized paper when we wanted it, although we generally had plenty of it around the laboratory. If none of it suited our purpose we generally carbonized what we required.

77 x-Q. Why did you use carbon made of paper in telephone and in your battery in preference to carbon made of anything else?

A. Because it was in convenient form. We could get it in all the forms we wanted it. We also carbonized wood of various kinds as well as paper.

78 x-Q. Had the carbon made of paper no other superiority for the purpose for which you wanted it beyond that of mere convenience in manufacture?

A. In our telephones we had to have it in agreat many experiments very thin. Hence paper was the most convenient material to use. For nearly all the purposes for which we used carbon it was the most convenient material. In our telephone experiments we used every kind and character of carbon, and every form and shape. In 1877. most all our thoughts were on carbon and plumbago. It was carbon from Monday morning to Saturday night, month in and month out, and always in connection with its interpolation in an electric circuit.

79 x-Q. When did you turn your attention to the subject of electric lighting?

A. In September or October, 1877.

80 x-Q. Please to describe the first electric lamp you made or caused to be made?

A. I think my first experiments were with heating platinum wires to incandescence. Afterwards, heating carbon paper up to incandescence in the atmosphere. Also, coating the carbon with powdered glass, which, in melting, was to protect it from the atmosphere.

Also with powdered silicon. Also in the lamp marked "Edison's First Incandescent Lamp." Afterwards by the passage of current through pieces of boron and silicon, rendering them incandescent. Also silicon and boron placed between carbon points. All these experiments, I believe, were conducted between September, 1877, and January, 1878.

81 x-Q. You do not answer my question, which is repeated.

A. The first carbon electric lamp, if it may be called an electric lamp, was a piece of carbonized paper, about an inch long, one-sixteenth of an inch broad, and six or seven thousandths of an inch thick, the ends of which were secured to clamps, which clamps formed the poles of a battery. The carbon was brought up to incandescence, and of course oxydized immediately. That was one of the '77 experiments. The first lamp in vacuo, if it may be called a lamp, was Edison's Exhibit First Incandescent Lamp. This consists, as will be seen, of two clamps, forming the poles, between which a strip of carbonized paper was placed and secured by clamping. The base of the lamp being placed over the mouth of the hole on the platen of the air pump, had the air exhausted from the globe, as far as possible, by our air pump, and the carbon brought up to incandescence after the air due to the first heating had been pumped out.

82 x-Q. Did your first experiment in electric lighting consist of a section of carbon made of paper placed in an electric circuit in the open atmosphere, to which you applied a current and burnt up the carbon.

A. I have already stated that I first tried platinum, but we will leave this out of consideration, and my answer will be yes. It was a mere experiment with the carbon in open air. I knew beforehand what it would do. It was to ascertain, I think, the amount of current required to bring it to incandescence.

83 x-Q. When was that experiment made? State the date, as near as possible?

A. It might have been in September or in October, 1877.

84 x-Q. Was it surely in one or the other of those months?

A. I am not absolutely sure, but my impression is it was in either one of those months.

85 x-Q. You are certain that it was in the year 1877?

A. Yes, sir; I know it from from my Exhibits Nos. 4 and 5.

86 x-Q. Was that the first attempt that you made to use carbon made of paper in electric lighting?

A. The first premeditated attempt to use paper for lighting by incandescence. I have stated that one of our objects in 1876 was to make carbons for electric lighting, but not by incandescence.

87 x-Q. When did you make your next attempt to use carbon made of paper in incandescent electric lighting?

A. In September, October or November, 1878. I should say October is the month we started to make paper carbon.

88 x-Q. You say that your first premeditated attempt at using carbon made of paper for incandescent electric lighting was in September or October, 1877, when you placed a piece of carbonized paper in circuit in the open air, for the purpose of ascertaining the amount of current to make it incandescent. And that your next attempt was in the fall of 1878. Now please to state whether this second attempt embraced the Exhibit "Edison's First Incandescent Lamps?"

> Question objected to by counsel for Edison as containing a misstatement of the witness' testimony.

A. My second attempt was not in the fall of 1878. I have already stated in my testimony that my first attempt at making an incandescent carbon lamp, if it can be called a lamp, was made in September or October, 1877, and consisted in bringing a strip of carbonized paper up to incandescence in the air. And my next attempt to make an incandescent lamp with carbon paper, if it may be called a lamp, was that shown in Edison's Exhibit First Incandescent Electric Lamp, which was also made in 1877, within a day or two of the first experiment. The attempts made at coating the paper with glass and silicon are not taken into consideration in this answer.

The taking of further testimony was adjourned by consent to Wednesday, June 15, 1881, at 10 o'clock, at the same place.

WM. H. MEADOWCROFT,
Notary Public,
New York County.

Pursuant to adjournment, this examination was resumed June 15, 1881, at 10 A. M., at No. 65 Fifth avenue, same counsel being present.

The witness, THOMAS A. EDISON, further answers to questions proposed by Amos. Broadnax, Esq., counsel for Sawyer & Man, as follows:

89 x-Q. Then, as I understand you, your first and second attempts at electric lighting with carbon made of paper were made either in the month of September or October, 1877, the second attempt being made within a few days of the first?

A. Yes, sir; lighting by incandescence of carbon paper.

90 x-Q. The first attempt was the use of the carbonized paper in the open air and the second embraced the lamp marked "Edison's Exhibit First Incandescent Lamp"?

A. Yes, sir.

91 x-Q. Do you fix the time at which these attempts were made by the Exhibits Edison No. 4 and Edison No. 5?

A. Yes, sir; these exhibits refresh my memory as to experiments conducted at that time and previous thereto.

92 x-Q. What is there upon Exhibit No. 4 that calls your attention to any experiments made in electric lighting by incandescence with carbonized paper?

A. The exhibit merely refreshes my memory so as to enable me to state the date of the time when I did try experiments with carbonized paper. The exhibit is headed "Electric Light," and explains itself.

93 x-Q. Do you find anything on the exhibit that makes any reference to electric lighting by incandescence with carbonized paper?

A. No, sir; I do not. I have already stated that the exhibit serves only to refresh my memory as to the date. The reason why boron and silicon were used is that they are not so sensitive to oxidization as the paper previously tried.

The last part of the answer is objected to by counsel for Sawyer & Man as irresponsive.

94 x-Q. In whose handwriting is Exhibit No. 4?

A. Most of it is in my own handwriting.

95 x-Q. There is a strip of Exhibit No. 4 torn out between the names of Mr. Charles Batchelor and J. Kruesi. Who tore that out?

A. I do not know. These papers were originally in books, and the books were all destroyed, and the sheets forming the same numbered and bundled together. The most of them were used as exhibits in my telephone interference.

96 x-Q. Was there any one else's signature written upon this paper between the names of Charles Batchelor and J. Kruesi?

A. I do not know. I do not think so. It looks as if it had been stuck on a paper file and torn off.

97 x-Q. Who made the diagrams upon this paper Exhibit No. 4?

A. I did.

98 x-Q. When were the diagrams and writing made upon this paper, so much of them as was made by you?

A. At the date stated thereon.

99 x-Q. There are two dates on the paper. Which date do you mean, the date on the right-hand corner at the top, under which your name is signed?

A. I refer to the date of November 1st, 1877.

100 x-Q. There is a memoranda at the bottom of the paper as follows: "Copied in Volume No. 1, experimental researches, page 115, September 28, 1878." Signed, William Carman. Who is William Carman?

A. He was at that time, and is now, my bookkeeper at Menlo Park.

101 x-Q. Does that memoranda show the correct date of the record of this paper?

A. It shows the date when it was recorded in the book, as set forth.

102 x-Q. Why was it not recorded until September 28th, 1878?

A. Because about that date we commenced collecting all the scraps and memoranda relating to experiments together, for the purpose of preseving them, and especially those relating to telephones, of which there were several thousand, now used as exhibits in the interferences on telephones.

103 x-Q. Have you got that book in which this paper is recorded, and, if so, will you produce it for my examination.

A. I have it at Menlo Park, I think. I will have it brought in.

104 x-Q. It appears by this paper that some time previous to November 1st, 1877, you had "tried boron, ruthenium, chromium, and the almost infusible metals for separators in my electric light device. Boron is very high resistance, and would do if arranged thus."

Then follows a diagram. It is then stated that "silicium, on the other hand, is of very low resistance, and would have to be arranged thus." Then follows another diagram. Then follows these words: "I think powdered silicium, mixed with lime or other very infusible non-conductors or semi-conductors, would be good." Now, if previous to the making of this paper by you, you had attempted the use of carbonized paper for incandescent electric lighting, how did it happen that you didn't mention it on this paper with the other substances or materials referred to by the paper?

A. Because I had got done with my experiments on carbonized paper. The results were so unsatisfactory, even when the carbonized paper was in the vacuum which we obtained. Its sensitiveness to oxidation was one of the factors which led me to try experiments on silicon and boron, which were not so sensitive to oxidation. I thought that as we could not get carbon to stand, that these non-oxidizable materials might be made to stand. I have had pieces of silicon, separating the two electrodes, incandescent for an hour at a time. Had the carbon experiments been as satisfactory, I would undoubtedly be able to present an exhibit in which some of them would be recorded.

104½ x-Q. Do the experiments referred to by this paper, Exhibit No. 4, make part of your efforts at electric lighting by incandescence ?

A. Yes sir ; as well as my Exhibit No. 5.

105 x-Q. Did you, at the time referred to by this paper, keep written memoranda of all your attempts at electric lighting ?

A. No, sir ; I do not think I did.

106 x-Q. Did you keep a written memoranda of all the experiments that yielded results of any value ?

A. No, sir ; I do not think I did. The exhibits themselves state that I tried experiments, and yet I have no record of them.

107 x-Q. What is there in the paper, Exhibit No. 4, that satisfies your mind, that your first and second attempt at electric lighting by incandescence with carbonized paper was previous to the date of the paper ?

A. It refreshes my memory as to the fact that I was trying experiments on electric lighting by incandescence, and it permits me to remember that my first experiments were with platinum and carbonized paper.

108 x-Q. Then, as I understand you, you know certainly by this paper, that the experiments noted on it were made on or before its date, which is November 1st, 1877, and to the best of your recollection, the experiments with the carbonized paper embraced in your first and second attempt at electric lighting by incandescence, were made previous to the date of the experiments noted on that paper ?

A. Yes, sir ; that allows me to fix the date.

109 x-Q. Did Mr. Charles Batchelor and Mr. J. Kruesi sign their names upon this paper in your presence at the time the paper was made ?

A. I cannot say ; our habit was to have the papers

witnessed within a day or two of the date placed upon them.

110 x-Q. Please to mark the diagrams on this paper, Exhibit 4, figures 1 and 2 respectively ?

A. I have done so, as requested.

111 x-Q. Does Fig. 1 of these diagrams represent a number of lamps set in multiple arc, and if so, please to designate the lamps by letter *a* ?

A. It does so represent, and I have designated them by letter a, a^1, a^2, a^3.

112 x-Q. State, if you please, whether Figure 2 represents lamps set in series, and if so, please designate the lamps by letter *b* ?

A. It does so represent, and I have designated the lamps, b, b^1, b^2.

113 x-Q. The word " magneto," as I understand it, written by the two diagrams, is intended to designate an electric generator ?

A. Yes, sir.

114 x-Q. Who is Mr. Charles Batchelor ?

A. He is one of my assistants.

115 x-Q. How long has he been in your employ ?

A. About ten (10) years.

116 x-Q. Who is Mr. J. Kruesi ?

A. A machinist in my employ.

117 x-Q. How long has he been in your employ ?

A. I think about seven (7) years.

118 x-Q. In whose handwriting is Exhibit Edison No. 5 ?

A. Nearly all in my handwriting.

119 x-Q. When was it made ?

A. On the day of its date, that is, December 3d, 1877.

120 x-Q. Was this paper, Exhibit No. 5, witnesses by Charles Batchelor, M. N. Force and J. Kruesi in your presence ?

A. I cannot say.

121 x-Q. Do you know the signatures of those gentlemen ?

A. Yes, sir.

122 x-Q. Can you swear that their signatures are signed upon this paper?

A. Yes, sir.

123 x-Q. Can you swear when the signatures were made?

A. No, sir; but my impression is, they were made within a day or two after the date on the paper; that was our habit.

124 x-Q. And this paper, Exhibit No. 5, assures you that the experiments noted on it were made on or before the day of its date, and that to the best of your recollection, your first and second attempt at electric lighting with carbonized paper was made before the date of that paper?

A. I have already testified that it was made before the date of Exhibit No. 4, which is an earlier date than Exhibit No. 5.

125 x-Q. Does either Exhibit No. 4 or No. 5 make any reference to your experiment with carbonized paper in electric lighting?

A. No, sir; they merely refresh my recollection as to dates.

126 x-Q. Who made Edison Exhibit First Incandescent Lamp?

A. I don't know; we bought it. It was a well-known school apparatus for illustrating the electric brush in vacuo. The changes necessary to try the experiment on carbonized paper were made by or through the orders of Mr. Charles Batchelor.

127 x-Q. Did you buy the lamp yourself?

A. I do not know, I cannot remember, but my impression is I did.

128 x-Q. Where did you buy it?

A. I cannot remember that, but my impression is I bought it of a firm called Luhme & Co.

129 x-Q. Where?

A. New York.

130 x-Q. Give the street and number in New York?

A. I don't know the street or number. It was down near the Post-office.

131 x-Q. Do you recollect what you paid for it?

A. No, sir?

132 x-Q. Was the place at which you purchased it, north or south of the Post-office?

A. It was south of Chamber street and north of Vesey street.

133 x-Q. Was it west of Broadway?

A. And west of Broadway.

134 x-Q. Is that as near as you can locate the place where you purchased the lamp?

A. Yes, sir.

135 x-Q. Have you now a distinct recollection that you did purchase the lamp yourself?

A. No, sir; I have only an impression.

136 x-Q. Who do you think would have purchased it if you did not?

A. It might have been purchased by letter or by messenger boy.

137 x-Q. You are sure it was purchased of the firm of Luhme & Co. in the City of New York?

A. No, sir, I am not; but my impression is that it was.

138 x-Q. Were you in the habit of dealing with that firm?

A. I was in the habit of dealing with that firm, and a firm named Benjamin & Co., I think.

139 x-Q. Where is the firm of Benjamin & Co.?

A. I think it was somewhere south of Chambers, north of Vesey and west of Broadway.

140 x-Q. What does Luhme & Co. deal in, and what does Benjamin & Co. deal in?

A. In philosophical apparatus.

141 x-Q. This lamp, Edison Exhibit First Incandescent Lamp, that you say you think you purchased, what was the name of the apparatus when you purchased it?

A. My impression is, it is called a "Gassiot Cascade."

142 x-Q. What alterations did you make in this cascade to adapt it to your purpose in making your ex-

periments in incandescing electric lighting with carbonized paper ?

A. Clamps were placed in it to hold the carbon, and binding posts outside to hold the conducting wires.

143 x-Q. How many experiments did you try with this lamp ?

A. My impression is that we tried two or three experiments.

144 x-Q. How large was the piece of carbonized paper which you used in this lamp. Give the length, the breadth and the thickness of it ?

A. My impression is that it was about an inch long, $\frac{3}{16}$ broad, and I think somewhere less in width than $\frac{3}{16}$; I should say they were eight thousandths of an inch thick.

145 x-Q Did you carbonize the paper especially for these experiments ?

A. I do not remember whether we used some carbonized paper we had on hand, or carbonized it expressly for the occasion.

146 x-Q. How did you get the carbonized paper in the lamp ?

A. Mr. Batchelor put it in.

147 x-Q. You don't know how he got it in ?

A. No, sir ; I don't.

148 x-Q. What degree of vacuum did you get in this lamp ?

A. My impression is we got two and half millimeters of mercury on a gauge, which represents, if the gauge was correct, that the column of mercury was within two and a half millimeters of a perfect vacuum.

149 x-Q. How much was the millimeter in inches ?

A. It isn't an inch ; two and a half millimeters are about a tenth of an inch.

150 x-Q. What was the resistance of the carbonized paper burner that you used in this lamp?

A. I did not measure it.

151 x-Q. What strength of current did you have on it?

A. We had about fifty cells of carbon battery, but I do not remember how many we used on it.

152 x-Q. Did you get the carbonized paper to brilliant incandescence ?

A. No ; I do not think so.

153 x-Q. How long did the carbonized paper last in the lamp ?

A. My impression is that it only lasted six or eight minutes.

154 x-Q. How long was you engaged upon these experiments with this lamp ?

A. I do not think more than a day.

155 x-Q. Were they made at your laboratory, Menlo Park?

A. Yes, sir.

156 x-Q. How did you exhaust the air out of the lamp?

A. By an air pump.

157 x-Q. Was it a pump you had on hand or did you buy it for the occasion ?

A. A pump I had on hand.

158 x-Q. Did you prepare the lamp for the experiment yourself, or did Mr. Batchelor prepare it ?

A. Mr. Batchelor.

159 x-Q. Did you see Mr. Batchelor put in the paper carbons?

A. I don't remember it.

160 x-Q. How do you know that paper carbons were actually put in the lamp ?

A. Because I told him to put them in, and I saw them after they were in.

161 x-Q. How could you distinguish a carbon made of paper from any other carbon?

A. Very easily, by its looks.

162 x-Q. How does it differ in appearance from carbon made of wood ?

A. It is very difficult to describe the difference in appearance, still, when once a person has seen the two he can distinguish them readily. The fibers of the paper are still visible after carbonization, while the wood shows the cellular formation.

163 x-Q. Why did you not continue your experiments

upon the use of carbonized paper for incandescent electric lighting in this lamp?

A. Because the results didn't warrant it?

164 x-Q. Upon the conclusion of your experiments with this lamp, did you abandon the attempt at electric lighting by incandescence with carbonized paper?

A. No, sir; we laid it aside and took up what we thought at the time was more promising—the use of silicon and boron for incandescent lighting.

165 x-Q. State, if you please, whether the paper marked Edison Exhibit No. 1, is an illustration of your first attempt at electric lighting by incandescence, with carbonized paper, in the fall of 1877, about which you have been testifying?

A. No, sir; it is an illustration of experiments conducted in the fall of 1878.

166 x-Q. In answer to question 9 of your examination-in-chief, which is as follows (counsel reads question and answer to witness). State, if you please, whether in that answer you referred to Edison Exhibit First Incandescent Lamp, which you subsequently produced?

A. Yes, sir.

167 x-Q. Then, as I understand you, the attempt illustrated by Edison Exhibit No. 1, followed the attempt embraced in Edison Exhibit First Incandescent Lamp; the latter being made in September or October of 1877, and the former in October or November of 1878. I mean, of course, in incandescent electric lighting with carbonized paper?

A. Yes, this Exhibit No. 1 is an illustration of experiments conducted in September or October, 1878, with incandescence of carbonized paper.

168 x-Q. Then this paper, Exhibit No. 1, as I understand you, represents your third attempt at incandescent electric lighting with carbonized paper?

A. No, sir; it represents the second in point of date. My understanding of "attempt" at incandescent lighting is, that it means all those experiments made within a few days of each other, forming a group. The experiments in 1877 are my first attempt, those in 1878 my second attempt, and those in 1879 my third attempt.

169 x-Q. Well, then, referring to Edison Exhibit No. 1, as your second attempt, please to state whether the exhibit is intended to represent the whole or a part of an experiment with carbonized paper in incandescent lighting in vacuum?

A. They represent a few of the experiments tried at that time on the incandescence of carbonized paper, but not in vacuo.

170 x-Q. Please to describe the first electric lamp or apparatus in which you used carbonized paper for incandescent electric lighting in vacuo, in October or November of 1878?

A. My impression is that it consisted of a piece of carbonized paper coated with tar and lampblack, and carbonized, placed in clamps connected to the circuit, and placed under the bell-jar of the vacuum pump. I am not absolutely sure that this experiment was tried in September or October, but it was tried not later than December, 1878.

171 x-Q. What do you mean by the "bell-jar" of the vacuum pump?

A. The bell-jar that usually accompanies vacuum pumps in which the vacuum is obtained.

172 x-Q. Was the bell-jar of glass?

A. Yes, sir.

173 x-Q. Please to illustrate the arrangement, and describe it by letters of reference?

A. This sketch represents the arrangement as I recollect it. A represents the platen and bell jar of the vacuum pump; B is the bell-jar; *c* is the platen; *d* and *e* are binding posts; *f* and *g* of figure 2 are metal pieces, connected through the iron of the platen to the binding posts; *h* and *k* are insulating pieces; *m* and *n* are metallic prongs which fit against these metallic pieces *f* and *g* when pressed down on their sides. This connects the circuit with *m* and *n*. The electrode *p*, holding the carbon, is connected to *n*, while the other electrode, connecting the other end of the carbon and marked Q, is connected by a wire with *m*. Thus the circuit was complete from one binding post to the other through the carbon when the bell-jar was on. The bell-jar represents the vacuum chamber of the pump in which the light was produced.

This sketch is put in evidence by counsel for Sawyer & Man as an illustration of the witness' testimony and marked Edison Exhibit No. 9.

174 x-Q. How many experiments did you make with carbonized paper in the vacuum chamber of this pump, as you have described?

A. My impression is that we made three or four experiments.

175 x-Q. Were the experiments made by you personally or in your presence?

A. I think they were made by myself and Mr. Batchelor, and perhaps Mr. Upton.

176 x-Q. Who prepared the pump for the experiments?

A. I don't remember.

177 x-Q. Did you witness the experiments yourself?

A. I witnessed some of them.

178 x-Q. Did you see the carbonized paper put in the vacuum chamber?

A. I saw it in the chamber. I don't remember seeing it put in.

179 x-Q. Are you able to swear, of your own knowledge, that the carbon in the vacuum chamber was made of paper?

A. Yes, sir; some were made of paper and some of carbonized broom corn.

180 x-Q. Were the papers carbonized expressly for the experiment?

A. I think they were carbonized for the experiment shown in exhibit 1, and had been carbonized previous to this last experiment.

181 x-Q. Do you mean that they were carbonized expressly for those experiments which you say were made in October or November of 1878, and were they

carbonized at the time of the making of those experiments?

A. Mr. Batchelor, I believe, had made fifty or more of these carbons for experiments in September or October, 1878, some of which are illustrated as used in Exhibit No. 1.

182 x-Q. What size were the carbons used in the experiments made with the pump?

A. My impression is that they were about one thirty-second in diameter, and an inch or two inches in length.

183 x-Q. Was the carbon that you used in Edison Exhibit First Incandescent Lamp, straight or curved?

A. Straight.

184 x-Q, What was the success of your experiment with carbon in the vaccum chamber of the pump?

A. We could not make the carbon stand, although we had pieces of potassium, and also sodium within the chamber.

185 x-Q. What was the resistance of the burner?

A. We didn't measure it.

186 x-Q. What was the strength of the current?

A. I think the strength of the current was four or five vebers, or four or five thousand foot pounds.

187 x-Q. What degree of vaccum did you have upon the burner?

A. I think about 2½ or three millimeters, which we read off from a mercury gauge which came with the pump and was the best vacuum generally obtainable with a pump.

188 x-Q. Please to describe the next lamp you made, if any, in Xctober or November of 1878, in which you used carbonized paper for incandescent lighting in a vaccum?

A. I don't think we tried any other experiments than the ones I have here recited in vacuo, in 1878.

189 x-Q. That, then, as I understand you, completes what you call your second attempt at electric lighting by incandescence with carbonized paper?

A. That, and including the devices illustrated in Exhibit No. 1, and patent No. 224,329, this arrangement being similar to that shown in Mr. Sawyer's patent 219,771, dated September 16th, 1879.

190 x-Q. Do you wish to be understood as saying that you made a lamp in the fall of 1878 like that shown and described substantially in patent 224,329, dated February 10th, 1880, and used carbonized paper in it for incandescent electric lighting?

A. Yes, sir; we used carbonized paper and carbonized broom corn in it in September, October or November, 1878.

191 x-Q. Does the specification making part of that patent, make any reference to the use of carbon made of paper?

A. No, sir, it does not; it merely mentions carbon, and does not mention the kind of carbon.

192 x-Q. Why did you not describe in that specification the use of carbon made of paper in that lamp?

A. Because that was not a part of the invention. We made these slender pencils of carbon, because it was the easiest way to make carbon, as we had no mill for grinding carbon or mold for molding it, and hence made the pencils in the most convenient way, such as coating paper with tar and rolling it up and carbonizing it, and also by carbonizing broom corn.

193 x-Q. Did you make and use an electric lamp like that of the patent last referred to in the fall of 1878?

A. Yes, sir.

194 x-Q. Then, in addition to the experiments made with the paper carbons in the vacuum chamber of the pump in the fall of 1878, you also experimented with the same kind of carbons in the lamp of the Patent 224,329, as I understand you?

A. Yes, sir.

195 x-Q. Were the experiments with the lamp of the patent referred to made in vacuo?

A. No, sir; they were made in the open air, and were to obviate the use of a vacuum.

196 x-Q. At the time you experimented with this lamp of the patent referred to had you discovered the

superiority of carbon made of paper for incandescent electric lighting over other carbon?

A. No; only it was very convenient materal to use.

The taking of further testimony was adjourned by consent to Thursday, June 16, 1881, at 10 o'clock A. M., at same place.

Wm. H. Meadowcroft,
Notary Public,
N. Y. Co.

Pursuant to adjournment, this examination was resumed June 16, 1881, at 10 A. M., at No. 65 Fifth avenue, same counsel being present.

Cross-examination continued:

The Witness desires to add to his last answer the following:

My answer is changed to this: No; only it was very convenient material to use, and was organic carbon.

197 x-Q. Referring now to Edison's Commercial Incandescent Electric Lamp, state when it was that you first made a lamp of the form and substance of this Exhibit?

A. I think duplicates of this lamp, as to form shape and material, were made some time in October, 1879.

198 x-Q. Have you got the original lamp of the form of this exhibit?

A. I have not been able to find it within the last two or three days, but my impression is that I can produce one of the first six made.

199 x-Q. Was the first one of the same size that this exhibit is?

A. The globe was about the same size. It was made in the same manner, except that the paper, which was parchmentized paper, was wider than it was thick, and was bent over in the form of an arch.

200 x-Q. Were the metal conductors put in in the same way they are put in this exhibit?

A. Yes, sir.

201 x-Q. Was there a section of platinum interposed in the conductor between the copper and the carbon?

A. Yes, sir.

202 x-Q. And the interior glass bulb was contained in it the same as in this one, was it, and the lamp sealed in the same way?

A. Yes, sir.

203 x-Q. Please to give the dimensions of the carbons used in those first lamps like this exhibit?

A. The first lamp of this peculiar character with paper carbon had a carbon about a thirty-second of an inch wide, six or eight thousandths of an inch thick, and about two inches and a half to three inches in length before carbonization. It was cut straight and had thickened ends, and was bent in the form of an arch before carbonization. After being put in the lamp the height of the arch, I should judge, was about an inch or an inch and an eighth. Within a day or two afterwards we cut loops out of paper of the form desired, the same as shown in my Exhibit Commercial Incandescent Electric Lamp, and the same as shown and described in my application in this interference.

204 x-Q. Referring still to the first lamps like this exhibit, state, if you please, what resistance the carbon had in those lamps?

A. The resistance of a unit length and mass of paper carbon is generally the same, whether the lamp has one ohm or a thousand ohms resistance. The resistance of the whole carbon probably was a hundred and twenty-five ohms cold, and perhaps seventy-five ohms at sixteen candles. Carbon decreases its resistance when heated, but not in direct proportion to the rise of temperature. I do not think we measured the resistance of the carbon in the first lamp, but only judged it.

205 x-Q. To what degree of perfection did you get the vacuum in the first lamps like this Exhibit Edison's Commercial Lamp?

A. My impression is that they were exhausted to the one millionth of an atmosphere.

206 x-Q. To what degree of luminosity did you raise the carbon?

A. I think we raised it as high as 30 or 40 candles.

207 x-Q. How long did it last, raised up to that degree of luminosity?

A. We did not keep it for more than half an hour at that degree of luminosity. My impression is that at from 12 to 16 candles it lasted over a hundred hours.

208 x-Q. Of continuous illumination?

A. Of continuous illumination; yes, sir.

209 x-Q. Referring now to this particular lamp, Edison's Exhibit Commercial Incandescent Lamp, you say in answer to Q. 33, examination in chief, that it burnt either 70 hours and 18 minutes, or 250 hours and 40 minutes. Can't you state any more definitely than that the time that the lamp did actually burn?

A. No, sir, I cannot. In my book, in which is recorded the life of 150 or more lamps, I find that the record of the life of this lamp is put down in ink as 251 hours and 41 minutes; but this has been partially scratched off, and 70 hours and 18 minutes substituted.

210 x-Q. And you cannot tell which is the correct data, as I understand you?

A. No, sir.

211 x-Q. Please to read from your record book all the memoranda and data you have in writing that refers to this particular lamp—Edison's Exhibit Commercial Incandescent Lamp.

A. I think I have other records of this lamp and will try to find them. I read now from the book referred to, page 39:

"Street lamp top of stairs, right-hand, 235. Resist. —January 2d, noon. Burnt, .40. January 3d, 19.30; Jan'y 4th, 9.58; Jan'y 5th, 20.50; Jan'y 5th, 3.47. 6, 20.26; 7, 12.15; 8, 22; 9, 9; 9, 6.50; 10, 19.15; 11, 7; 12, 11. Total time burnt, 70.18. Carbon busted.

Total time burned, 207.36 up to 5 P. M.

251.41 up to noon."

A portion of the record is scratched out.

212 x-Q. Please to permit me to examine the record from which you have read in answer to the last question.

Witness hands the record to the counsel.

213 x-Q. Does this record show the resistance of the lamp?

A. No, sir.

214 x-Q. Does it show the luminosity of the lamp?

A. No, sir.

215 x-Q. Does it show the degree of vacuum in the illuminating chamber?

A. No, sir.

216 x-Q. Does it show when the record was made?

A. It shows that it was January 2d, at noon, but does not state the year; but on page 38, one page before this record, lamp 153, a date (January 2d, 1880) is recorded, and I know that this was in 1880. Lamp 153 had a resistance of 132 ohms and lasted over 200 hours.

Last part of answer objected to by counsel for Sawyer & Man as irresponsive and impertinent, as no inquiry is being made about the record of lamp 153.

217 x-Q. Can you swear that this record you have quoted was made January 2d, 1880?

A. I can swear it was made within four or five days of that date. I think I shall be able to produce a witness who made these records.

218 x-Q. In whose handwriting is this record you have quoted?

A. In Mr. Batchelor's handwriting, and Mr. Herrick's, I think.

219 x-Q. Which of it is in Mr. Charles Batchelor's handwriting and which of it is in Mr. Herrick's handwriting?

A. The words, "Street lamp, top of stair, right-hand. Resist. Burnt, 40," are in Mr. Charles Batchelor's handwriting, and all the rest is, I think, in Mr. Herrick's handwriting.

220 x-Q. How does it happen that the date of the record is January 2, noon, and the burning of the lamp appears to have commenced on January 3d, and continued down to January 12th, taking the whole of the dates into account, including those that are crossed out?

A. It could not have commenced on January 3d, because the record states that up to January 3d it had burned 19.30, which means 19 hours and 30 minutes from January 2d; it had also burned 40 hours before January 2d.

221 x-Q. Apart from this record, have you any distinct recollection of the burning of this lamp?

A. I have an indistinct recollection. It would be a hard matter to recollect any particular lamp out of a hundred nearly all alike. Upon the lamp it is marked "Depot," and I remember it there. It was in a very conspicuous place and must have been seen by many thousand people.

222 x-Q. You did not make this record yourself, as I understand you, and did not see it made?

A. I did not make it myself. I don't remember that I saw it made; but I remember that I watched these records pretty closely, and must have seen it within a day or so after it was made.

223 x-Q. How does it happen that the whole record was not made by one person?

A. I think because Mr. Batchelor started the record and then got an assistant to carry it out more in detail. He will doubtless be able to testify on that subject.

224 x-Q. Are you able to swear that the record was made as it appears here, all at one time, and that that time was during the performance of the lamp that is noted here?

A. I am able to swear that I believe it to have been made in the manner and on the dates set forth in the record.

225 x-Q. Is part of the record in lead pencil and part of it in ink?

A. Yes, sir.

226 x-Q. Please to state what part is in lead pencil?

A. Figures "235, street lamp, top of stairs, right hand. Resist. Burnt 40. Jany. 2, noon, 70.18;" and some cross pencil marks.

227 x-Q. Please to state what part of the record remains intact—that is not crossed out?

A. "235, street lamp, top of stairs, right hand. Resist. Burnt 40. Jany. 3d, 19.30; 4, 9.58; 5, 20.50. Total time burned: 70.18; Jany. 2, noon."

228 x-Q. Is the rest of the record crossed out with ink and lead pencil?

A. Yes, sir.

229 x-Q. Who crossed it out, and when was it done?

A. I don't know who did it, or when it was done.

230 x-Q. Now, this lamp, Edison's Exhibit Commercial Lamp, and those few that preceded it, about which you have testified this morning; embrace, as I understand you, your third attempt at electric lighting by incandescence, with carbonized paper?

A. I testified regarding a few, but there were more than a hundred made by the end of December, 1879, all of this character, with carbonized paper. These constitute my third attempt in connection with all that I have done since.

231 x-Q. What I want to know, Mr. Edison, is whether this lamp and all the lamps that you made having the form and substance of this lamp, "Edison's Exhibit Commercial Incandescent Lamp," embraced your third attempt at electric lighting by incandescence, with cabonized paper?

A. In October we commenced making lamps of the same character as to form, with paper carbon, as shown in Exhibit Edison's Commercial Incandescent Lamp, and have continued to make them ever since. This is my third and successful attempt at lighting by the incandescence of carbon made from paper.

232 x-Q. Do you mean to swear, now, that your first and second attempts at electric lighting by incandescence with carbonized paper, were successful?

A. The first attempt I did not consider successful, except that it showed that if carbon could be made to stand, that it could be made successful; and my second attempt was successful in the form shown in patent No. 224,329, but in vacuo it was not successful, except that it proved that carbon from paper or organic material would be a success for lighting by incandescence, if it could be made to stand.

233 x-Q. How long did you use the lamp of patent 224,329?

A. My impression is that we used it several days.

234 x-Q. Have you got any memoranda in writing of its performance?

A. I do not think I have—that is dated.

235 x-Q. Have you got any written record that you can swear represents the performance of this lamp?

A. I think among my records I may have something, but in hunting I neglected generally those records that have no dates.

236 x-Q. How much of the time did you use this lamp with carbonized paper?

A. I should say carbonized paper was used in it on and off several hours, burning. In this lamp we used both carbonized broom-corn and carbonized paper.

236½ x-Q. Is the illuminating portion of this lamp intended to be enclosed in a glass chamber?

A. Yes, sir; partially of glass.

237 x-Q. Between the time that you discontinued your experiments in the electric lighting by incandescence with carbonized paper, in the fall of 1877, and the time you commenced to experiment again upon the same subject in the fall of 1878, as you have testified, was you engaged any of the time in experimenting upon electric lighting by incandescence?

A. My impression is that I did try some experiments in electric lighting by incandescence, but can find no record to refresh my memory.

238 x-Q. If you have any distinct recollection of any

experiments made within the period mentioned in my last question, please to describe them?

A. I only have an impression.

239 x-Q. You can't describe any experiments?

A. No.

240 x-Q. Now, between the time that you discontinued your experiments in incandescent electric lighting with carbonized paper, in the fall of 1878, and the time you commenced them again with carbonized paper, in the fall of 1879, did you make any experiments in electric lighting by incandescence?

A. Yes.

241 x-Q. What substance or material did you use for the illuminating portion of your lamp in such experiments?

A. Platina and other materials.

242 x-Q. How much of the time embraced within my question (240 x-Q.) were you engaged in experimenting with platinum and material other than carbon?

A. Except, perhaps, some experiments with carbon, in January, 1879, we were engaged night and day between the times named.

243 x-Q. During the period included in my x-Q. 240, how many experiments did you make in incandescent electric lighting with carbon that was not made of paper?

A. I don't remember any experiment made with carbon that was not made with carbon paper, or carbonized broom-corn.

244 x-Q. What experiments did you make with carbon made of paper, in January, 1879?

A. In some form of lamp analogous to that shown in Patent 224,329.

245 x-Q. Please to describe the lamp in which you employed carbon made from paper, for incandescent lighting, in January, 1879?

A. It was a lamp similar to Figure 2 in the Patent 224,329.

246 x-Q. How did it differ from the lamp described in the patent mentioned in your last answer?

A. I think the carbon was shoved down by a spiral spring.

247 x-Q. How much carbonized paper did you use in such lamp?

A. Perhaps a length of it; about two or three inches.

248 x-Q. Can you produce that lamp?

A. No, sir; it is substantially the same kind of a lamp as that shown in Figure 2, Patent 224,329.

249 x-Q Was the carbonized paper used in vacuo?

A. No, sir.

250 x-Q. What was your object in making this experiment with carbonized paper, in January, 1879?

A. To make what we call a "shop-lamp"—one in which the current only had to be subdivided in a shop, and not over a large area, where a high resistance was not absolutely essential.

251 x-Q. Why did you use carbon made of paper in preference to carbon made of anything else in that lamp and for that experiment?

A. Because it was easy to make, and produced the proper kind of contact desired, and we had no means of making hard carbons with any degree of facility.

252 x-Q. Was the paper specially carbonized for that experiment?

A. I cannot remember.

253 x-Q. Was the experiment made in your presence?

A. I think I made it myself.

254 x-Q. What was the result?

A. It worked fairly.

255 x-Q. Why have you not mentioned this experiment in your previous testimony?

A. I forget why; perhaps because the question has not been asked me.

256 x-Q. Did you make any other experiments between the fall of 1878 and the fall of 1879 with carbonized paper for incandescent electric lighting than those you have already testified about?

A. No; I think not with carbonized paper.

257 x-Q. Have all of your attempts of electric lighting been by incandescence?

A. No, sir; not all, but most all.

258 x-Q. Is it your conviction now that electric lighting by incandescence can be successfully accomplished with carbon made of paper in vacuo?

A. Yes, sir; it was successfully accomplished by me.

259 x-Q. State, if you please, when it was that you first reached the conviction that electric lighting could be successfully accomplished by carbonized paper in vacuo?

A. In September or October, 1879; that it could be accomplished by the use of carbonized paper in high and stable vacuo, which were the proper conditions.

260 x-Q. Did you, previous to September or October, 1879, make and use carbonized paper for electric lighting by incandescence in vacuo successfully?

A. I have already testified on that point quite clearly. My answer will be the same as answer to x-Q. 232.

261 x-Q. The answer to x-Q. 232 does not answer my last question, which is repeated?

A. My previous answer answers it perfectly.

262 x-Q. What do you understand by the word "successful" in the relation that I used it in x-Q. 260?

A. Several understandings have passed through my mind. Sometimes an experiment is a successful experiment when it don't work, if it proves positively or negatively, or shows possibilities. It may or may not be considered successful, and in my answer to x-Q. 232 I have stated fully about the success and non-success of these experiments.

263 x-Q. In cross-question 260 I did not ask you anything about experiments, but about successful lighting, and I now ask you again when you first succeeded in lighting successtully by incandescence with carbonized paper in vacuo?

A. If you mean when I first succeeded successfully in lighting up a piece of carbonized paper in vacuo by electrical incandescence I will state that it was done in Edison's Exhibit First Incandescent Lamp.

264 x-Q. How long did you say you succeeded in illuminating that lamp with carbonized paper in vacuo?

A. Several minutes, but the vacuum was a poor one.

265 x-Q. Well, how many minutes?

A. Perhaps ten minutes.

266 x-Q. Do you consider an electric lamp that goes out in ten minutes successful lighting by electricity?

A. It is the successful lighting of the lamp for ten minutes by electricity.

267 x-Q. Are you now making and using incandescent electric lamps in which you use carbonized paper for the illuminating portion of the lamp in vacuo?

A. Yes, sir.

268 x-Q. How do the lamps you are now making and using differ from the Exhibit Edison's Commercial Incandescent Lamp?

A. Differ only in shape.

269 x-Q. How does the shape differ from the exhibit?

A. The carbon is in the form of an arch, but does not come together at the electrodes so near as in the Exhibit.

270 x-Q. Is the glass chamber of the same form?

A. Some lamps are and some are pear-shaped.

271 x-Q. Is the carbon of the same dimensions you have given of the carbon in the exhibit?

A. Pretty near the same, I think; I have none here for comparison.

272 x-Q. How many of these lamps have you in use?

A. I cannot say; they have been sent all over the world. We have a stock on hand for use when other necessary appliances are ready.

273 x-Q. State approximately how many you have sold or have in use?

A. We have sold three or four hundred.

The taking of further testimony was adjourned by consent to Friday, June 17th, 1881, at 10 o'clock, at same place.

Wm. H. Meadowcroft,
Notary Public,
N. Y. Co.

Pursuant to adjournment, the examination was resumed June 17th, 1881, at 10 A. M., at No. 65 Fifth avenue, same counsel being present.

Counsel for Edison produces record book containing the copy of Edison's Exhibit Nos. 4 and 5, and submits it to the inspection of counsel for Sawyer & Man.

274 x-Q. Referring now to your record book, No. 67, pages 1 to 15 inclusive, of which Exhibit No. 3 is an alleged copy, please to state whether this record was kept by you personally?

A. No, sir; it was not.

275 x-Q. Please to state by whom it was kept?

A. Partially by Charles Batchelor, and partially by a man named Herrick, I think.

276 x-Q. Was it kept by those persons in your presence?

A. I was present. I should say almost all this time in the room with the parties when this record was made.

277 x-Q. In whose handwriting is the record?

A. Partially in Batchelor's, partially in Herrick's, I think, and some of my writing is on it.

278 x-Q. Were the entries made in that record by the different persons mentioned, all made at the same time?

A. About January 1st, 1880, it was decided to keep the burning time of the lamps manufactured, and this record was the starting point of the time, and was started in a systematic manner by Mr. Batchelor, I believe, on January 2d, 1880; and he, I believe, put down on January 2d the numbers of the lamps, their position, and the time they had burned previous to January 2d; and thereafter the exact burning hours were kept by him and Mr. Herrick; and the entries, I believe, were made the day after the date on the entries.

279 x-Q. These lamps to which the record refers, when were they made?

A. Sometime in December, 1879.

280 x-Q. Is a portion of this original record in lead pencil?

A. Yes, a very small portion.

281 x-Q. By whom was that portion of it made?

A. One portion by myself, and the other portion by Charles Batchelor.

282 x-Q. When did Mr. Batchelor make his entries in lead pencil, and when did you make yours?

A. I made mine January 5th, 1880; Mr. Batchelor has dated his entry January 2d, 1880, 8 P. M. I believe that I know that he made that entry at that time.

283 x-Q. Are the figures in ink that notes the day of the month, the number of hours and minutes the respective lamps, burned, in the handwriting of Mr. Herrick?

A. I think part of them are in Mr. Batchelor's handwriting, and part in the writing of Mr. Herrick.

284 x-Q. And these figures were made, you think, either on the day of the date or the day after?

A. Yes, sir; I think they were.

285 x-Q. Do you know that of your own knowledge?

A. Yes, sir; I am almost certain.

286 x-Q. When did you get the vacuum pump illustrated by Edison Exhibit No. 6?

A. That particular shape of vacuum pump was made some time in September, 1879.

287 x-Q. Previous to getting that pump, did you succeed in getting a satisfactory vacuum in your lamps? I mean a vacuum in which your carbon burners would endure incandescent for any reasonable length of time?

A. Yes, sir.

288 x-Q. When did you first succeed in getting such a vacuum?

A. I think it was in August, 1879, that we had a pump that would produce a vacuum up to perhaps the hundred thousandth part of an atmosphere.

289 x-Q. Was that the first you obtained the necessary vacuum in your lamp?

A. My impression is that that was the first pump by which a partially satisfactory vacuum was obtained.

290 x-Q. Referring now to Edison's Exhibit No. 2, being the "New York Herald," or part of it, dated December 21st, 1879, state, if you please, whether you wrote or caused to be written the article headed "Edison's Light," on page five, and to be illustrated as there illustrated?

A. No, sir; I did not write it, nor did I cause it to be written.

291 x-Q. Did you revise or examine it after it was written and approve of it?

A. No, sir; I did not.

292 x-Q. Are its statements true?

A. Some are and some are not. The article seems mostly to be made from my patents, into which a great deal of romance has been injected.

293 x-Q. Are the illustrations true illustrations of the lamp referred to in the article?

A. Not strictly true. Most of them have been taken from the patents. Two I recognize as having been taken from the "Scientific American."

295 x-Q. Which of the illustrations are correct, and which are erroneous? Please mark the figures?

A. The figures are substantially correct as illustrations. Figures 8 and 9 are copied from the "Scientific American's" articles. Figures 1, 2, 3, 4, 5 and 6 seem to be taken from patents or caveats. Figure 7, I do not know how that was obtained. It is substantially correct, but not correct in detail.

296 x-Q. State, if you know, who is the author of the article?

A. I believe a reporter of the "New York Herald" named Edwin Fox, was the author.

297 x-Q. What part of the article is true, and what part romance?

A. That which is descriptive of the apparatus is substantially correct. The rest is an ingenious weaving in of the experiments and talk at the laboratory, and imagination of the reporter, into a separate article, in a proper form to appeal to the imagination.

298 x-Q. Within a few days after the publication of that article, do you recollect of telling any one, that it was true every word of it, or something to that effect?

A. No, sir; I don't recollect of telling any one that it was true every word of it. I might have been asked by a number of people if that "Herald" article was correct, and might have replied that it was correct, meaning that the results I had attained had been attained.

299 x-Q. What degree of vacuum is it necessary to maintain in the chamber of your lamp to make the carbon endure in a state of incandescence for one hour, so as to produce a luminosity equal to 15 candles?

A. Never having tried that exact experiment I cannot state.

300 x-Q. What degree of vacuum would be necessary to be maintained to ensure the endurance of the carbon in a state of incandescence equal to a luminosity of 15 candles for two hours?

A. Never having tried that exact experiment I cannot say.

301 x-Q. Same question, during a period of three hours, or four hours, or five hours, or any number of hours of which you have actual knowledge, as to the endurance of the carbon illuminated to the degree of incandescence mentioned in my question No. 299?

A. I cannot give exact results, but my impression is, from noticing lamps having poor vacuums, and lamps on the pump where there was a guage, that generally the carbon would not last at that incandescence more than four or five hours when the barometrical mercury column showed a vacuum of only about a millimeter. This has reference to my lamp when it is to be worked in vacuum.

302 x-Q. Does the invention described in your application for a patent in this interference include a vacuum in the illuminating chamber of the lamp?

Question is objected to upon the ground that as the application itself is in testimony it is the best evidence.

A. The application itself is the best evidence of that.

303 x-Q. What does the application say upon the subject.

Same objection as before.

A. Being in evidence it can be referred to to ascertain what it says.

304 x-Q. I have no complete copy of the application, nor has any been put in evidence; please to read from the specification, if you have one, what is said upon that subject?

Question objected to, for the reason that the application by the rules of the Patent Office is a part of the record testimony, and counsel for Sawyer & Man is entitled to a copy at any time by asking for it at the Patent Office and paying for it.

Counsel for Sawyer & Man states that counsel for Mr. Edison prompts the witness by putting a copy of the specification in his hands and telling the witness to say that he would very cheerfully read the specification if he had a copy of it, but does not know whether his copy is a correct copy, his copy being retained, papers or roughs of the specification in which many alterations seem to have been made.

A. I have no specification which I am sure is a correct one.

305 x-Q. Do you know whether the carbonized paper burner, making the subject matter of this interference, is intended to be illuminated in vacuum?

A. That is one of the intentions, according to my recollection.

306 x-Q. Do you know whether the carbonized burner making the subject matter of this interference is intended to be illuminated in a glass chamber from whence the air has been exhausted, and as inert gas substituted in the chamber?

A. It was intended mainly to be worked in vacuum, but I also intended and did try some of these paper carbon loops in a sealed glass receiver containing an inert gas, or intended to be inert.

307 x-Q. How long did the paper carbon loops tried in the inert gas endure when they were illuminated?

Question objected to as not being proper cross-examination.

A. I do not remember.

308 x-Q. State as nearly as you recollect?

A. The ones I saw, I think, lasted five minutes; and, perhaps, one of them lasted an hour, or even two hours.

309 x-Q. Did you make the experiments yourself?

A. No, sir.

310 x-Q. Who made them?

A. I think one of the parties was named Francis Jehl.

311 x-Q. Where were they made?

A. At my laboratory, at Menlo Park.

312 x-Q. When were they made?

A. My impression is they were made either in December, 1879, or January, 1880.

313 x-Q. What gas was used in the chamber?

A. I did not analyze it.

314 x-Q. Don't you know?

A. I know what we intended to use.

315 x-Q. What did you intend to use?

A. Hydro-carbon gas, hydrogen gas, nitrogen gas, hydro-chloric acid gas and chlorine gas, I think.

316 x-Q. How many experiments did you make?

A. I saw two or three.

317 x-Q. What kind of gas was the chamber filled with in the experiments that you saw?

A. I didn't analyze it.

318 x-Q. Don't you know?

A. I would not absolutely know without analyzing it.

319 x-Q. Do you know what was intended to be used?

A. I have already testified that gases were intended to be used, but cannot be certain as to which gas was used in the experiments I saw.

320 x-Q. Do you know whether any of these gases were used in a state of purity in charging the illuminating chamber of the lamp?

A. I don't know that they were pure.

321 x-Q. Do you know at what pressure the gas was put in the chambers of the lamps?

A. My impression is at atmospheric pressure.

322 x-Q. Have you made or caused to be made any other experiments in illuminating by incandescence with paper carbon in a sealed lamp filled with inert gas than those you have referred to in the immediate preceding answers?

A. Yes, sir: I have made them with a gas which is supposed to be inert.

323 x-Q. When were these other experiments made?

A. While not intended, the lamp Exhibit Edison's First Incandescent Lamp did have a gas in it formed by the decomposition of the grease used in the lamp at the joints, as I have already stated in my evidence, and at times, since January, 1880, lamps have been made in which simple and compound gases have been used, experimentally, to determine theoretical points. I have also used in the early part of 1879, perhaps in December, 1878, gases, especially hydrogen, in a lamp giving light by incandescence, but in this case platinum was used.

324 x-Q. Does electric lighting by incandescence with carbon in sealed lamps charged with inert gas, make any part of the invention described in your application for a patent in this interference, or intended to be described in that application, or does it make any part of your system of electric lighting by incandescence?

> Counsel for Mr. Edison objects to all that portion of the question which relates to the specification on the ground that the specification itself is the best evidence.

A. The specification itself will be the best answer that I can give the question, and I do not desire to state what I intend or what I do not intend to use in my system of electric lighting.

325 x-Q. Has electric lighting by incandescence with carbon in sealed lamps charged with inert gas heretofore made any part of your system of electric lighting by incandescence?

A. I have already testified that I have tried the same, and as I had a system of electric lighting at Menlo Park at the time, these formed a part of the system at that time.

326 x-Q. Do you mean to swear that you have used at Menlo Park a system of electric lighting by incandescence in which carbon was used as the illuminating portion of the lamp, in an atmosphere of inert gas in a sealed lamp?

A. Yes, sir; such a lamp formed part of a system of lighting by incandescence of carbon at Menlo Park.

327 x-Q. When?

A. In December, 1879, or in January, 1880, I think.

328 x-Q. What kind of carbon did you use?

A. Carbon made out of paper.

329 x-Q. How long did you use that system?

A. The system is still there.

330 x-Q. How many lamps did you use of the kind I have described in my question No. 326?

A. We have used on that system at Menlo Park, I should say, as many as thirty lamps, but as to the inertness of the gas on the carbon, I am not sure as any gas whatsoever has an effect on the carbon.

331 x-Q. How many sealed lamps have you used that were charged with gas that was intended to be

inert, and the illuminating part of which was made of carbonized paper?

A. I have already testified that no gas is inert and therefore I could have made no lamps in which it was inert.

332 x-Q. (Question repeated.)

A. No lamps that were inert, because I knew that no gas could be used that was inert, all gases having effect on the carbon.

Answer objected to as irresponsive.

333 x-Q. (Question repeated.)

A. I have already testified to that question.

334 x-Q. How many sealed lamps have you used that were charged with gas, commonly called inert, and the illuminating part of which was made of carbonized paper?

A. My impression is that half a dozen were made.

335 x-Q. How long did you continue to use them?

A. I did not see more than two or three and those didn't last more than from fifteen minutes to an hour.

336 x-Q. State, if you please, whether the Exhibit Edison's First Incandescent Lamp is the apparatus referred to in answer 9 of your examination in chief?

A. Yes, sir.

337 x-Q. What experiments have you made in treating carbons for electric lighting, made of paper, electrically in a hydro-carbon gas?

A. The experiment with the First Incandescent Lamp might be considered an experiment with a hydro-carbon gas; I have tried other experiments in treating paper with an atmosphere of a hydro-carbon gas since that time.

338 x-Q. Please to relate what experience you have had in treating carbon electrically in a hydro-carbon gas, for the purpose of enlarging or purifying the carbon, or consolidating it?

Question objected to as a cross-examination upon matter not involved in this interference, and involved in another interference to which Sawyer & Man are not parties.

Counsel for Sawyer & Man says that the witness in his examination-in-chief has expressed opinions about the utility and practicability of treating carbons in that way, and the question is pertinent to matters testified to by the witness in his examination-in-chief.

A. I have brought up to incandescence a carbon within a lamp containing a hydro-carbon; I have done it in a great number of lamps, a hundred or more; I have tested the economy, the conductivity and other properties of the carbon, and have examined the same many times under a powerful microsope.

339 x-Q. When did you make the experiments?

A. They were made previous to the declaration of this interference; a hydro-carbon gas was used, I think, in December, 1879, and '80, but not for the purpose set forth in your question.

The taking of further testimony was adjourned by consent to Saturday, June 18, 1881, at 10 o'clock, at same place.

Wm. H. Meadowcroft,
Notary Public,
N. Y. Co.

Pursuant to adjournment, this examination was continued June 18, 1881, at 65 Fifth avenue, New York, same counsel being present.

340 x-Q. Have you had any experience in treating carbon for illuminating purposes in electric lamps, electrically in the presence of hydro-carbon gas or fluid previous to putting them in the sealed illuminating chamber of the lamp?

Question objected to as an improper cross-examination, no inquiry having been made about the same in the examination-in-chief.

A. Yes, sir.

341 x-Q. Please to relate what experience you have had in treating carbons in that way, and give the dates of your experiments?

A. I have no memorandum with me which would refresh my memory as to the dates, but it was previous to the declaration of this interference that I tried experiments of heating to incandescence a carbon conductor in a hydro-carbon gas within a fluid, and also heating a carbon conductor to incandescence by an electric current in a gas within a chamber not sealed.

342 x-Q. How many carbon burners have you treated in that way?

A. I should say twenty or thirty.

343 x-Q. When did you do it—state as nearly as you can recollect?

A. Some time between March and September, 1880.

344 x-Q. Is that as near as you can give the date?

A. Yes, sir, as I have no memoranda here, not thinking that this question would come up.

345 x-Q. Please to describe your method of treating these carbons in hydro-carbon gas electrically, including the apparatus you used in your experiments?

Same objection as before was repeated.

A. As the details of the mechanism which I used is the subject matter of another interference, I refuse to answer.

> Counsel for Sawyer & Man insists upon a responsive answer to this question, and gives notice that unless the witness answer the question he will move to strike out the deposition.

346 x-Q. (Question repeated.)

A. I have already described them sufficiently. I stated that the carbon was brought to incandescence by electricity when within a gas within a liquid, and also when within a gas within a chamber not sealed.

347 x-Q. What kind of a chamber was it, and how was the carbon conductor arranged in the chamber, and what kind of hydro-carbon fluid and gas did you use?

A. It was a glass chamber, the carbon was within the chamber so arranged so that the electricity could pass through it, and gasoline was used.

348 x-Q. How did the treatment affect the carbon treated?

A. It brought its resistence down and deposited a crust of hard carbon over its surface which under the microscope showed a multitude of projecting points which were found to be hollow when broken.

349 x-Q. Of what material was the carbon made that you treated?

A. Both paper and bamboo.

350 x-Q. After you had treated the carbon did you put it in the sealed chamber of an electric lamp and raise it to incandescence, and if so with what result?

A. Yes, sir; some of them we did. The result was that it was lower resistance and seemed to be more susceptible to destruction by electrical carrying than the untreated carbons.

351 x-Q. To what degree of luminosity did you raise it?

A. Varying degrees of luminosity.

352 x-Q. Please to name them?

A. I think as high as a hundred candles.

353 x-Q. How long did the carbon burner last raised to the luminosity of a hundred candles?

A. My impression is that it lasted about two hours. It was a very fine filament.

354 x-Q. Please to give its dimensions?

A. I cannot give its dimensions. We had carbons of various dimensions. These were tried on very fine filaments. It was a thinner one than that shown in the Exhibit "Edison's Commercial Incandescent Electric Lamp." It was a little longer. I should say it was a quarter of an inch longer. I am referring to the one that lasted two hours, yielding a hundred candle power.

355 x-Q. Was it in vacuum?

A. Yes; in very high vacuum.

356 x-Q. Does the successful use of the lamp described and illustrated in the application of the patent involved in this interference necessitate a high vacuum in the illuminating chamber?

A. In a commercial sense it is my opinion, which results from my experiments, that it is essential to have a high vacuum in the lamp chamber, for the reasons I have heretofore stated.

357 x-Q. Are you now manufacturing incandescent electric lamps substantially like that described and illustrated in the application for the patent involved in this interference, commercially?

A. The Electric Lamp Company, with which I am connected, are manufacturing lamps of this kind and selling them to electric light companies.

358 x-Q. What company do you refer to as that with which you are connected, that is manufacturing these lamps commercially?

A. The Edison Electric Lamp Company.

359 x-Q. What proportion of the lamps so manufactured by the Edison Electric Lamp Company are fitted with carbon burners made of paper?

A. From one and a half to two per cent., I should say. I have not looked over their books lately. I know that a man is now engaged, and has been at different times in the last three months, in making paper carbons for use at the lamp factory.

360 x-Q. Are the carbon burners with which these lamps are fitted made upon the plan described in the application for the patent involved in this interference?

A. Yes.

361 x-Q. Please to give the dimensions of these carbon burners?

A. I should say they were about an eighth of an inch, perhaps a quarter of an inch, shorter than the one shown in the Exhibit Edison's Commercial Incandescent Lamp.

362 x-Q. How does it compare in diameter to the burner referred to in your last answer?

A. I should judge that it was a shade wider, but have no idea as to how thick it is.

363 x-Q. What, no idea as to how thick it is?

A. If it was a foot thick, I think I should probably have an idea; but as these filaments are always made out of thin paper, I cannot state whether it is thicker or thinner than the one in Edison's Commercial Incandescent Lamp.

364 x-Q. Please to give, as nearly as you can, the dimensions of the carbon burner in Edison's Commercial Incandescent Electric Lamp?

A. I guess it is about an inch and a quarter from the top of the clamps to the top of the loop; about seven-eighths of an inch from one side of the loop to the other. I should judge that the width was twenty-thousandths of an inch, and five-thousandths of an inch thick.

365 x-Q. To what degree of luminosity are these lamps, which you say the Edison Lamp Company are manufacturing commercially, fitted with carbonized paper burners, brought or intended to be brought in practical use?

A. Sixteen candles, I believe.

366 x-Q. How do you measure the candle power of a burner?

A. With a photometer.

367 x-Q. What photometer do you use to measure your candle power?

A. The Bunsen spot photometer.

368 x-Q. Referring again to the Exhibit Edison's Commercial Incandescent Lamp, please to state, as near as you can, what its luminosity was during the time of burning, as noted in the record about which you have heretofore testified, and of which you have given a transcript of, page 39?

A. My impression is that the average candle power would be about from twelve to sixteen candles.

369 x-Q. You say that about one or one and a half per cent. of the lamps that are manufactured by the Edison Electric Lamp Company are fitted with carbonized paper burners. Please to state what is the whole

number of lamps manufactured by that company per day?

A. About a thousand per day.

370 x-Q. Have you ever made any carbons from several thicknesses of blotting paper pressed together under a hydraulic press?

A. I have made carbons of several thicknesses of blotting paper pressed together under a screw press, but not under a hydraulic press.

371 x-Q. Where is the Edison Electric Lamp Company situated, I mean its factory?

A. At Menlo Park and at Newark.

372 x-Q. Does that company sell lamps to any one who may wish to purchase them?

A. Yes, in foreign countries, and in this country by the permission of another company, the Edison Electric Light Company.

373 x-Q. Does that company treat the carbon burners of their lamps electrically in the presence of hydrocarbon gas before they use them for illumination, I mean the Edison Electric Lamp Company?

A. Not lately.

CROSS-EXAMINATION ENDED.

Counsel for Edison, in pursuance with the notice given at the close of his examination-in-chief, puts in evidence Letters Patent of Thomas A. Edison No. 224,329, dated February 10, 1880; 227,227, dated May 4, 1880; 227,228, dated May 4, 1880; 227,229, dated May 4, 1880; 223,898, dated January 27, 1880; also specification of English Patent of Thomas A. Edison No. 2402, June 17, 1879; also Letters Patent 205,144 of Sawyer & Man, dated June 18, 1878; 210,152 of Sawyer & Man, dated November 19, 1878; 210,-809 of Sawyer & Man, dated December 10, 1878; 219,771 of Wm. E. Sawyer, dated September 16, 1879; 211,262 of Sawyer & Man, dated January 7, 1879; 229,335 of Sawyer & Man, dated June

29, 1880; 227,118 of Albon Man, dated May 4, 1880.

It is stipulated between counsel for Edison and Sawyer & Man that the Government printed copies of these patents may be read in evidence with the same force and effect as if they were certified copies put in evidence and marked as exhibits in the case, counsel for Edison agreeing to furnish counsel for Sawyer & Man with at least three of each of such printed copies; and it is further stipulated that the said Government printed copies of all the patents put in and referred to as evidence on behalf of Sawyer & Man with like effect, counsel for Sawyer & Man agreeing to furnish counsel for Edison with at least three of such printed copies. Said patents to be subject to all legal objections, nevertheless, that might be taken or urged against them if they were regularly put in evidence as exhibits; and coun el for Sawyer & Man objects to the above-mentioned patents as evidence in this case, on the ground that they were not pertinent or relevant or competent as evidence upon any issue in this controversy, and request counsel for Edison to state upon the record how such patents are competent, relevant, or material upon any issue in this controversy.

Counsel for Edison replies that when the matter comes up for hearing an attempt will be made to show that such evidence is material.

RE-EXAMINATION OF THE WITNESS BY GEORGE W. DYER, OF COUNSEL FOR EDISON:

371 Q. Referring to your answers on cross-examination, as to your experience in making and using carbons of paper in 1876 and 1877, did anything remain to be done by you prior to 1878, to determine the qualities essential in the paper carbon for an incandescent conductor for an electric lamp?

Question is objected to upon the ground that it does not appear by any of the witness' answers on cross-examination that he made any carbons of paper in 1876 and 1877, for electric lamps, nor does it appear from anything the witness has said, either upon his examination-in-chief or his cross-examination, that he successfully used carbonized paper for electric lighting by incandescence previous to the fall of 1879; and upon the further ground that all of the witness' testimony intended to prove or going to prove that he made the invention, or any part of it, previous to the date alleged in his preliminary statement, is inadmissible under the rules of the Patent Office and its well established practice; and upon further ground that the question is intended to bring out matter upon which the witness was previously examined in chief, and not upon anything new brought out in cross-examination.

A. No, sir.

372 Q. Referring now to your answer upon cross-examination, when did you first determine the sufficiency of carbonized paper *per se* for an incandescent conductor for an electric lamp?

> Question objected to because it is indefinite as not referring to any particular answer to any question on cross-examination and upon the further ground that the question is not when he first determined the sufficiency of the carbonized paper burner, but when he first proved its sufficiency by actual use; and upon the further ground that the question refers to experiments made before the time given in the preliminary statement.

A. I knew from my experiments in 1876 and 1877, where I employed carbonized paper and other carbonized organic substances for resistances, that carbon in that state of aggregation had high resistance as compared to hard or coke carbon, and was the proper form to use for incandescent conductors for electric lamps, if they were to be worked in multiple arc, and the experiment with the strip of carbon in the open air, and in the Exhibit Edison's First Incandescent Electric Lamp, used in 1877, also showed its adaptability and sufficiency for multiple arc lighting.

373 Q. In 1877 did you require any further information or experiments to determine the sufficiency of incandescent conductors for electric lamps made with carbonized paper?

> Question objected to as referring to a date previous to the date of the preliminary statement, and also as not bearing upon the question of when witness did make the invention in the interference by its actual and successful use, and on the further ground that the witness has already been examined in chief on that very point?

A. No, sir.

374 Q. Referring again to your answer upon cross-examination, wherein you stated that since your experiments in electric lights had been resumed in 1878, you had been working upon the same day and night, please give in a general way the nature of your labors in electric lights up to 1880, and the assistants employed by you and the general nature of their duties.

A. In the fall of 1877, having about finished my labors with my carbon telephone, I had several ideas which I desired to work up, one of them being the subdivision of the electric light; hence I commenced experimenting for that purpose, as my testimony and exhibits show. These experiments continued, I think, until January, 1878, when my time and attention was absorbed by the excitement caused by the invention and exhibition of the phonograph. This continued until July, when my health being broken down by several years of continuous labor, I went to California and other places West, spending about two months. On my return, in August, 1878, I immediately took up the experiments made in 1877, but interrupted by the phonograph and the state of my health, and have continued them night and day ever since. About December, 1878, I engaged a mathematician named Mr. Upton to assist me in working out the complicated problems as to economy and adaptability of the various devices necessary to make a complete system of electric light by incandescence which would be capable of replacing or competing with gas, over large areas, such a system comprising main conductors, house conductors, lamps of various characters, meters, dynamos, electro-motors of various kinds and characters, apparatus for regulating the pressure of the flow of electrcity through such system, arrangement of the system of conductors for equal distribution of the electricity, safety devices, boilers, steam-engines, electro-meters, photometers and other appliances. I had other assistants, among whom may be mentioned Francis Jehl, John Kruesi, Charles Clarke, Charles Batchelor, William Hammer, Mr. Herrick, Dr. Haid, Mr. Lawson, Martin Force, Dr. Moses, E. H. Johnson and many others who were employed in 1878 and 1879. Possibly Clarke and Hammer may have started work in the early part of 1880.

Answer objected to as to all work and experiments made before the date given in the preliminary statement in so far as such relates to the issue in controversy.

Postponed until Monday, June 27th, 1881, at 10 A. M., at 65 Fifth avenue, New York, by consent.

Wm. H. Meadowcroft,
Notary Public,
N. Y. Co.

Thomas A. Edison resumes his testimony as follows, this 30th day of June, 1881:

375 Q. In your answer to question 374 you have not stated the nature of the duties of the assistants employed by you; please do so now?

A. Francis Jehl was employed generally to assist in any kind of experiments; John Kruesi was foreman of the machine shop; Charles Clarke, mathematician and mechanician; Charles Batchelor, principal assistant on general experimenting; William Hammer, assistant on vacuum pumps; Mr. Herrick, time-keeper for the lamps; Dr. Haid and Mr. Lawson, chemists; Martin Force, assistant on any experimenting; Dr. Moses, chemist and assistant on general experimenting; E. H. Johnson, assistant outside of laboratory generally.

376 Q. Have you been present this morning during the examination of J. Kruesi, and have you seen the memorandum book produced by Mr. Kruesi and marked Edison's Exhibit No. 12?

A. Yes, sir; I have.

377 Q. In view of the testimony of Mr. Kruesi, and of your examination of his memorandum book, Exhibit 12, are you able to refresh your memory as to dates of early experiments with electric lamps?

A. I undoubtedly tried some experiment with an electric lamp about the time stated in the book Edison's Exhibit No. 12, but I cannot remember the nature of the lamp or recall to memory the results of these experiments.

378 Q. Are you satisfied in your own mind that the repair of an air pump noted in the memorandum book Exhibit No. 12, under date of January 29, 1877, had some connection with an electric lamp?

A. Yes, sir; my impression is strong that the pump was used in connection with the electric lamp, as I cannot conceive what other use it could be used for about that time, and could conceive that it could be used for an electric lamp.

379 Q. Since ceasing to give the testimony which

you have now resumed has search been prosecuted for exhibits relating to early experiments in electric lights, and, if so, with what results?

A. Yes, sir; Mr. Batchelor has found two or three exhibits, one of which is in my handwriting, which I now produce.

Witness produces a paper which is put in evidence and marked Edison's Exhibit No. 13. Exhibit objected to upon the ground that it is intended to prove the invention in controversy was made or conceived of previous to the time stated in the preliminary statement, and upon the further ground that it is immaterial to any issue in controversy.

380 Q. Please examine the paper Edison's Exhibit No. 13, state when it was made, how you know that fact, and what it shows?

A. The sketch was made October 5th,1877. It is signed by myself and is in my handwriting. It is witnessed by Charles Batchelor. It is headed, "Electric Light," and illustrates the principle for subdividing the electric light. The top figure represents a circuit in which there are resistances, around which are incandescent electric lamps consisting of two electrodes with silicon between them. The second figure represents the same kind of electric lamps worked in multiple arc. The third represents them worked in series.

381 Q. Does this Exhibit No. 13 refresh your memory as to the production of, and experiments with, Edison's Exhibit First Incandescent Lamp, about which you have testified, and if so, how does it refresh your memory?

Objected to as going to show that the invention was made previous to the date alleged in the preliminary statement of Mr. Edison.

A. It does. It refreshes my memory as to the date that I tried the first incandescent lamp. Because I went from the carbon on to experiments with silicon; owing to the sensitiveness of the carbon to oxidation, and I know that the carbon experiments were previous to the date of this exhibit, October 5th, 1877.

382 Q. Since you gave your testimony before in this case, have you been constantly absent from this office?

A. Yes, sir; I have.

Counsel gives notice that he here closes his re-examination of Mr. Edison, and offers him for re-cross-examination.

382 x-Q. What qualities must paper carbon have to render it sufficient for an incandescent conductor in an electric lamp?

A. The paper should be free from adulterations, and compact and well carbonized. It will then have a high resistance per unit length and thickness, and if cut as a filament the lamp in which it is used will have high resistance.

384 x-Q. What qualities must any carbon have to render it sufficient for an incandescent conductor to an electric lamp substantially like Exhibit Edison's Commercial Incandescent Electric Lamp.

A. My impression is that all kinds of carbon, except, perhaps, the diamond, are the same, and their different appearances are due to their structural arrangement. I think that hard gas retort carbon and paper carbon are the same kind of carbon, and the difference consists in their structural arrangements. Paper carbon, wood carbon, and in fact all carbon derived from vegetable organic matter of cellular formation when carbonized are very porous, hence the resistance to the passage of the current through a square millimeter section, and one inch long of paper carbon or wood carbon would be very much less than if the same was made of hard retort carbon, and as a high resistance is a desirable thing to make a commercial incandescent lamp, then paper and other organic carbon has the desirable property, owing to its cellular structure of giving such high resistance. Almost any kind of carbon could be used under the conditions of the lamp marked Edison's Commercial Incandescent Electric Lamp, and the same results could be obtained as to candle power and amount of energy. But the quality, or rather the aggregation of the carbon to form the incandescent conductor, should be such as to offer high resistance to the passage of the current to allow of commercial subdivision. And this quality organic carbon is possessed of.

Answer objected to by counsel for Sawyer & Man as irresponsive.

385 x-Q. (Question repeated, and counsel disclaims any desire to induce the witness to reveal any new discovery he may have made in the treatment or quality of carbon, but asks him to state merely the qualities that he thinks the carbon should possess to make it suitable for an illuminating conductor in an incandescent electric lamp.)

A. I do not think I can make my answer any plainer than I have already done.

386 x-Q. Must it have the quality of hardness and uniformity of texture?

A. It must have uniformity of texture, but it is not essential that it should be hard, that is, the carbon as a whole.

387 x-Q. Must the texture of the carbon be fine?

A. No, sir; it is not essential.

388 x-Q. Must it be solid?

A. No, sir; I prefer to have it structural—formed of cells.

389 x-Q. Must it be cellular, and must the cells be small or fine?

A. It must be aggregated together in such a manner that the total weight of the carbon between the two electrodes shall, with a given radiating surface, be far less than if the carbon was perfectly dense, and the interstices may be large or small within the carbon.

390 x-Q. Then, as I understand you, it does not matter whether the interstices or cells be large or small, provided the total weight of the carbon between the two electrodes shall, with a given radiating surface, be far less than if the carbon was perfectly dense?

A. No, sir; I speak within the limits of the ordinary size of organic vegetable cells.

391 x-Q. Must the carbon have a high resistance?

A. The burner, as a whole, should have a high resistance, for reasons I have already stated.

392 x-Q. When did you first discover that carbon made of paper would offer a high resistance to the passage of the current, to allow of commercial subdivision, so as to make it a suitable illuminating conductor for your lamp; I mean Edison's Commercial Incandescent Electric Lamp?

A. I knew that it had high resistance from my use of it in 1876 in rheostats and in my telephonic experiments in 1877, and that it had a proper resistance to admit of subdivision in multiple arc. In my Exhibit No. 4 I have placed the boron, which is high resistance, in multiple arc, and the silicon, which is low resistance, I was compelled to use in series, and I was perfectly aware when I made the Exhibit First Incandescent Lamp that organic carbon was the proper kind to use, as with a small mass it had high electrical resistance.

Last part of the answer objected to by counsel for Sawyer & Man as irresponsive.

393 x-Q. What was there in the experiments you made with Edison's Exhibit First Incandescent Lamp that enabled you to determine that carbon made of paper would offer a high resistance to the passage of the current, so as to allow of commercial subdivision, as you have stated?

A. I have already stated that I knew it beforehand.

394 x-Q. Then there was nothing, as I understand you, in the experiment that added to your store of knowledge upon that point?

A. Not regarding the resistance of organic carbon, except confirmatory of what I already knew.

395 x-Q. Then, as I understand you, when you made or caused to be made the lamp, Edison's Exhibit Commercial Icandescent Electric Lamp, you knew, not from any experiment upon the subject, but from your knowledge of the properties of paper carbon, that it would make a suitable illuminating conductor for your electric lamp, that it would offer a high resistance to the passage of the current and would allow of commercial subdivision?

Question objected to upon the ground that it does not correctly state the testimony of the witness upon this subject, he having testified to experiments in 1876 which resulted in his knowledge of certain qualities pertaining to paper carbons.

A. I have already stated that I knew from my experiments in the use of carbonized paper in rheostats in 1876, in telephones in 1877, confirmed by the experiments in 1877 on the first incandescent lamp and in 1878, also on paper carbons, that such carbon had such a high resistance as compared to its radiating surface as to admit of commercial subdivision, providing the incandescent conductor could be made small enough and be burned under proper conditions.

396 x-Q. When did you ascertain whether or not the conductor could be made small enough and burned under the proper conditions?

A. I ascertained and obtained the proper conditions to allow of the conductor being made small enough sometime in October, 1879. This was when it was placed in high vacuum.

397 x-Q. Without any reference to your experiments with your first incandescent lamp, did you know from your experiments with paper carbon in rheostats in 1876, and in telephones in 1877, that it would make a suitable illuminating conductor for an incandescent electric lamp?

Question objected to as obscure and misleading.

A. I knew upon the day that I tried the experiment on the first incandescent lamp that such carbon would be suitable, which knowledge, as far as its resistance was concerned, was derived from experiments in measuring its resistance in 1876 and 1877, as I have stated.

398 x-Q. Then, as I understand you, by your experiments with carbonized paper in rheostats in 1876, and in telephones in 1877, you had ascertained the resistance of carbon made of paper. Now, how did your experiments with Edison's first incandescent lamp prove to you that carbonized paper would be suitable for an illuminating conductor in an incandescent electric lamp?

A. That experiment was not to prove the resistance of the paper carbon, but to ascertain if it could be made to stand at a high temperature.

399 x-Q. Then, as I understand you, it was by that experiment that you determined the sufficiency of incandescent conductors for electric lamps, made of carbonized paper, as stated in answer to question 373 of your re-direct examination?

A. I did not require any further experiments to ascertain whether paper carbon was applicable to incandescent lighting. I knew it was applicable, if conditions could be obtained under which filaments of it could be made stable at high incandescence.

400 x-Q. When did you first ascertain that carbon made of bamboo possessed the requisite qualities for an illuminating conductor in an incandescent electric lamp?

Question objected to by counsel for Edison as not being proper cross-examination, nor pertaining to any matter brought out in direct examination and not involved in this interference, and advises the witness not to answer the question.

A. I decline to answer.

401 x-Q. Why do you decline to answer?

A. In the first place I do not see as the counsel has any business to ask the question; second, it is not in the controversy; third, my counsel advises me not to answer it; and fourth, that it would require hunting for exhibits, dates and other data to give the proper answer, which I am not prepared to do.

Counsel for Sawyer and Man, in view of the witness' refusal to answer, decline to further cross-examine the witness, and requests the examiner to certify the question to the Judge of the United States Circuit Court of the southern district of New York.

THOMAS A. EDISON.

By consent the taking of further testimony was postponed to July 7th, 1881, at 10 A. M., at the same place.

WM. H. MEADOWCROFT,
Notary Public,
N. Y. Co.

End of Edison's Interference Deposition.

Continuation of Edison's McKeseport Deposition.

ORANGE, N. J., March 6, 1889.

THE WITNESS, THOMAS A. EDISON, BEING FURUHER INTERROGATED, AS A PORTION OF HIS DIRECT EXAMINATION BY R. N. DYER, ESQ., COUNSEL FOR THE DEFENDANT, TESTIFIES AS FOLLOWS:

402 Q. Referring to your answer to question 61 in the interference, and which has now become a portion of your deposition in this case, is the opinion therein expressed as to the practicability of the Sawyer-Man lamp changed by an inspection of the description and drawings contained in that patent, No. 317,676, as issued—giving your reasons for any opinion you may express.

A. I find that the patent is issued, that is to say No. 317,676, is, in a great many respects, different from the application which was in interference at the time I gave my testimony. It has been changed so much from what it originally was as filed that the answer will be somewhat different to that given in the interference case. In my interference testimony I stated that no lamp has ever yet been devised, up to the present time, that was practical, which had an enclosing chamber partially made of a cup of metal and secured to the glass by cement. I find in the patent of 1885 that a plate of glass had been substituted for the metal case which I understood they had in the original application; but, as this glass portion of the lamp performs no new function, the substitution in my answer of glass for a cup of metal arranged as shown in the new patent does not change the fact that no practical lamp has ever yet been devised, up to the present day, whereby the enclosing chamber is made in two parts, and a cementing substance or air-excluding substance is the medium for joining the said two parts of glass together to form a chamber. All incandescent lamps, to my knowledge, at the present date, have this union sealed so that the lamp shall be one which is utterly, absolutely and wholly of glass, and not of two parts of glass put together by some substance which is not glass. At the time of the first interference I understood from the specifications, before they had been amended, that the lamp was to be used in an atmosphere of an inert gas, but in the altered specification more prominence is given to the use only of a vacuous space. Hence, my answer to question 61 would be modified by this fact. I cannot see how a vacuum can be maintained in a lamp made according to the specifications of the 1885 patent to Sawyer & Man. Up to the present date I am entirely unaware of any person constructing a vacuous transparent space which would maintain a stable vacuum of the character shown in the said patent of 1885, where the lamp is not wholly of glass. On the ordinary air pump, where a bell jar of glass rests upon a platen of glass, and where unctious and other substances are used between the two ground surfaces, stable vacuums are impossible to obtain with the present state of perfection of air pumps. This being the case, and there being no difference between the air pump and the Sawyer-Man patent of 1885 in respect to the case (and, in fact, it is against the patent and in favor of the air pump), and the facts being as I have stated, I cannot see how a commercial and practical lamp could be made by any means set forth in the specifications. I have no other amendment to make to my answer to question 61 in the interference case.

403 Q. What advantages, if any, would a construction such as is described in the patent in suit, having a glass plate secured to the bottom of the chamber, have over a similar construction provided with a metal plate or cap so secured?

A. I can see no advantage scientifically, and commercially a metal plate would be very much easier to get in shape; and, as a vacuum must be maintained by some substance at the junctures, the difference as to glass or metal would be immaterial. The metal might perhaps have some advantage by slowly oxydizing and taking up some of the residual oxygen in the vacuum, due to the heat which would be conducted through it by conduction through the electrode strips.

404 Q. The patent in suit speaks of the fact that the wall forming the chamber of the lamp is "made wholly of glass, by which all danger of oxidization, leaking, or short circuiting is avoided." What is your opinion as to the validity of these advantages?

A. I do not find in the patent that the chamber is made entirely of glass. It seems to be made of two parts of glass, with some material between the joints to prevent leaking.

405 Q. What I want to know is whether, in your opinion, the advantages stated in the matter I have quoted from the patent in suit are fanciful or real?

A. Leaving out the misstatement in the patent, that the chamber is made wholly of glass, the mere substitution of glass for metal does not diminish the leakage, because the leakage will not take place through the metal or the glass, but at the joints. As to the glass avoiding the danger of oxidization—if this refers to the oxidization of the carbon—then I should say that the metal had an advantage, as it would actually take up oxygen that might be left in the lamp. Regarding short circuiting, the same cementing material which is now used around the electrodes could be used to insulate the same from the metal. If such cementing material failed to prevent short circuiting, it would also fail to maintain the vacuum.

406 Q. To what character of construction in incandescent lamps do you understand the expression, "made wholly or entirely of glass," applies?

A. Where the chamber is really and truly made wholly of glass through which the platinum wires are passed, and are sealed thereto, and not to glass chambers in two parts, cemented or held together by material which serves to prevent the joints leaking. The great improvement in the art, and one which made the conditions for the use of fine filaments practical, and which advanced electric lighting to a commercial basis, was the use of a chamber entirely of glass, so that no possible leakage of air could take place, even in the most minute degree; for the slightest leakage, going on continuously, would render the excessively fine filament necessary for the commercial subdivision of electric light, impracticable to use. Were this class of lamps, with this chamber as shown in the patent of Sawyer & Man the only means known to-day, lighting by incandescence with filaments of carbon could not be a commercial success.

407 Q. Please explain the construction of the incandescent lamp chambers which you consider answer to the description of being made wholly of glass?

A. A chamber made wholly of glass, with no other material whatsoever, through which the platinum conducting wires pass and are sealed to the glass chamber itself by fusion—such platinum wires having the same coefficient of expansion as the glass itself.

408 Q. Do I understand you to mean a chamber made in one continuous piece of glass, and without joints?

A. No; but one wholly of glass as the result of the manufacturing operation.

409 Q. Would a glass chamber having a separable joint be such a chamber?

A. If there was nothing in between the joints; but in that case you could not maintain the vacuum.

410 Q. Have any patents been issued to you in which the lamp chamber is described as being wholly or entirely of glass; and if so, please state what they are, or the earliest of them?

A. My electric lamp patent No. 223,898, of January 27th, 1880, has such a chamber entirely of glass. This patent states the different advantages of chambers made entirely of glass over those made with joints. My patent No. 227,229, of May 4th, 1880, also shows a chamber made entirely of glass containing the incandescent burner. The latter specification also contains subject matter relating to the advantages of a chamber, made entirely of glass, in contradistinction to being made with joints.

411 Q. When were the applications for these two patents filed?

A. The patent No. 223,898 was filed November 4th, 1879; the patent No. 227,229 was filed April 21st, 1879.

Printed Patent Office copies of the two patents referred to by the witness are offered in evidence and are marked respectively "Defendant's Exhibit, Edison Patent, 223, 898," and "Defendant's Exhibit, Edison Patent, No. 227. 229;" and it is stipulated by counsel that these printed Patent Office copies may be used in evidence in lieu of regularly certified copies of the patents; and the same stipulation is now entered into between council as to all such copies hereafter offered in evidence, and also as to blue book copies of English patents.

412 Q. Referring to your answer to question 4, what do you mean by "carbonizing under strain and pressure," and of what importance is this in the manufacture of carbons for incandescent electric lamps?

Objected to by Mr. Kerr as incompetent.

A. It is important in carbonizing conductors for incandescent lamps, that they should be restrained from free movement during the act of the decomposition of the cellular, or other compounds, into carbon; otherwise, especially if they are filements, they are greatly distorted, so as to be useless; and if distorted, there is an unequal stress among the particles of carbon, which caused unequal resistance, and a liability to rupture by the expansions produced by the high temperature used with the carbon. If this decomposition or change from the vegetable to the carbonaceous state takes place under strain and pressure, equal conductivities of heat to the same necessarily takes place through the means used to cause the carbonization under strain and pressure. It is one of the most important things in the production of an incandescent conductor, especially if the same is filamentary in character, as more or less life of the filament depends on a greater or lesser perfection in the devices for producing this result. I have a number of patents showing means and methods of carbonizing incandescing conductors under strain and pressure; and I have done a large amount of experimenting, and even to this day I am still experimenting on more perfect means of producing absolute equality and simultaneous decomposition of the whole of the incandescing conductor, so that it will be as nearly homogeneous as it is possible to make it; as the life of the filament when in the lamp depends very largely on such even carbonization.

413 Q. Kindly call attention to the patents, or some

of them, that you have in mind in making your last answer?

Objected to by Mr. Kerr as incompetent.

A. Patent No. 248,423 of October 18th, 1881; Patent No. 263,144 of August 22d, 1882; Patent No. 263,139, of August 22d, 1882. I think I have more of those, but I do not see them at present.

414 Q. Would the disastrous distortion and unequal carbonization be prevented by packing the slips in powdered carbon, without any additional devices?

A. To a certain extent; but there is very little strain or stress on the carbon in this condition of carbonization, and you do not get so homogeneous a carbonization, although you prevent in a great measure distortion. Such incandescing conductors will not have the same life as those which are carbonized under proper conditions as to strain and pressure, although such incandescing conductors are sufficient where the same are to have a coating of hard carbon put on their exterior by what is known as the "flashing" process. Absolute homogenity of the carbon is not so essential as where the same is to be used without any subsequent treatment by the deposition of carbon, which deposited carbon really diverts the current from the original carbon, and which hard deposited carbon relieves the carbonized carbon from doing as much work as it would if used without the deposited carbon.

415 Q. In your deposition in the interference case (which is now a part of your present deposition) you refused, in answer to cross-Q. 400, to state when you first ascertained that carbon made of bamboo possesses requisite qualities for a conductor of an incandescent electric lamp. Have you any objections at the present time to making that statement? If not, kindly do so?

A. About the last of January or near the 1st of February, 1880, we found that lamps which we made out of bamboo splints gave us abnormally greater life at

high incandescence than any of the incandescing conductors made from other materials.

416 Q. What is the present material you use for your carbon filaments?

A. Bamboo.

417 Q. Do you use all kinds of bamboo, or some special kinds?

A. We use a special kind of bamboo. This quality of bamboo is found and cut for us specially in Japan. As soon as I found that bamboo had such great advantages over other materials that we had been using I dispatched a man to China and Japan to make an investigation and send me samples of all the different qualities of bamboo which he might find there. He went to different parts of China and Japan and sent me about forty different varieties of bamboo in such quantities as to enable me to make a number of lamps of the qualities which were suitable; and from the results of the life test on these lamps I ascertained which was the best species of the bamboo family for my purpose. He then made further investigation to ascertain the best parties to furnish a continuous supply, bamboo being an industry in Japan, and plantations in certain districts being the principal industry. From that time on I have got my supply of bamboo from the same place. However, I have kept up my search for different qualities of bamboo which might prove better, and also for all kinds of other material. Since 1880 I have sent one man up the Amazon; afterwards another was sent to Uruguay and to Paraguay, and up the river De La Platte; and two more men were afterwards sent up the Amazon to near its head waters; and two other men were sent to the West India Islands, and thence to the north coast of South America, from British Guiana to the United States of Columbia, up the Magdalena River to the headwaters at Honda. Another man was sent down to Mexico. One man just returned the other day from a years' search through Ceylon and India; and I have now a man down in the Cauca Valley in the United States of Columbia. In fact I have, since that date, always had men out searching for vegetable material which had the quality that I desired. Also through numerous correspondents I have received an enormous number of samples. I should say that I have received and carbonized, made into lamps, and tested their enduring qualities, not less than six thousand different species of vegetable growths.

418 Q. How large a proportion of these vegetable growths did you find at all suitable for your purposes?

A. Only about three species of bamboo, and one species of a peculiar cane that grows up in the regions of the Amazon, but of which I have never been able to procure a supply, owing to the malaria and fevers there; and one or two species of fibres from the agava family.

419 Q. Out of these vegetable growths that you have found suitable, did you find it possible to use the entire plant, or only particular portions. State what the fact is?

A. Of the bamboo, which we now use, only the extreme outer edge of the cylinder, after the removal of the silicious epidermis, can be used.

420 Q. How large a portion is that of the entire thickness which is suitable?

A. The thickness of the walls of the cylinder is about three-eighths of an inch; and we use twenty thousandths of this; but the best portion is the first ten-thousandths of an inch from the edge. It is at this point where the fibres are more nearly parallel and where the cell walls of the fibres are apparently the smallest and where the pithy matter between the fibres is at its minimum.

421 Q. In cutting or forming the filaments from the bamboo or other vegetable fibre, is it necessary that it should be done in any particular way; or will cutting in any way or direction answer the purpose?

A. No; it must be cut parallel with the fibres. We cut them as nearly parallel with the fibres as possible, and then by a system of inspections after the bamboo blank is ready for carbonization, we throw out as far as possible all those slips in which the fibres were not cut parallel. If we did not do this, and should cut so that the fibres at one end did not extend continuously to the other end, but one set of fibres, or rather, one or two fibres of the several fibres only extended half way up, where, by the cutting tool, they ran to a taper, and then to nothing, and nearly joining two similar fibres running to the other extremity, there would not be a continuous fibre from end to end in the blank. Hence, on carbonization there would be a break between the two fibres, composed of light, porous and pithy matter; and, after the filament had been carbonized, put in a lamp, and brought up to incandescence, the total weight of carbon being less at this particular point, and therefore offering a greater resistance to the passage of the current, it would become more highly heated than at the other points, and develop a "spot" as it is called by lamp makers, and the life of the lamp would be rather short.

422 Q. What would be the effect of attempting to cut a conductor from bamboo, the direction of the cut being at right angles to the length of the fibre?

Counsel for complainant objects to this line of examination in reference to bamboo as incompetent and irrelevant; and states that this objection would have been entered sooner but that it was agreed that it might be entered at the end of the examination. Counsel, however, prefers to enter it now, as the examinations seem to be an undue waste of time and entirely irrelevant to the controversy. So much of it as relates to anything done by the witness subsequent to the filing of complainant's application for a patent, is further objected to as incompetent and immaterial.

A. It would be impossible to cut a filament in that way, and even if it could be done I should not imagine that it could be carbonized successfully, or used at all.

423 Q. Referring to an incandescent conductor of the size shown in the patent in suit, what would be the effect of attempting to make a conductor by cutting a

piece from vegetable fibre, the cut being at right angles to the fibres, and then carbonizing the piece so cut. Would such a carbon have any value in the art in your opinion?

A. If the fibres of the material were all parallel and they were cut at right angles, of course they would be of no earthly use.

424 Q. Why would such a conductor be of no use?

A. In all vegetable growths formed of fibres that I have ever seen the fibres are separated from each other by pithy growths, having a cellular structure enormously greater in size than the cells of the fibres; and the proportionality of carbon which this light, porous matter gives, as to the proportion given by the fibre itself, would be several times less; that is to say, in the bridge between fibre and fibre there would be several times less carbon than in the fibre; and if such a filament could be cut, and if cut could be carbonized, and if carbonized could be put in a lamp, the passage of the current sufficient to render the fibres themselves incandescent, would bring the temperature of the intervening carbon, due to the pith, so extremely high that the lamp would immediately break. It would be like taking a lot of shot, placing them in a row and cementing them together with mucilage to make a wire, and using this wire to sustain heavy loads.

425 Q. How far would these defects which result from cutting across the fibres be present in woods generally?

A. We soon found out in our experiments that filaments could not be successfully made from wood for two reasons: First, all the woods which grow from the outside have fibres which are not parallel, the parallellism being more or less distorted in different woods by fibres which run towards a centre at right angles to the principal fibres and which are called, I believe, medulary rays. Wherever these pass the fibres on each side are bowed to permit these fibres to pass, and as the fibres at right angles are only connected by the other fibres with pithy matter, we would in a measure obtain a filament from ordinary wood like cutting bamboo at right angles to the fibre. In the mechanical operation of cutting, these small fibres which run at right angles to the principal fibres would pull out. The fibres of the filament would very seldom be continuous on account of the want of parallelism due to the bowing of the same around the medullary ray fibres; and all the lamps that we made from this class of material were of no commercial value whatever. The second objection to the woods is that the microscope shows that the cells composing the fibres are of very large dimensions, so large that the resulting carbon is very porous and friable, while in the slips cut from vegetable growths like bamboo (that grows from the inside and not from the outside like wood), the cells are of a very much smaller size, and consequently greater in number, and are greatly incrusted and filled with resinous and other amorphous material, which on carbonization softens and serve to lock the whole together in a homogeneous mass. There is not sufficient of such material in ordinary woods; and where the resinous matters are very great, as in the conifers, the most of it distills off as hydro-carbons of the turpine series, and leaves very little asphaltic residium to lock the carbonaceous residium together.

426 Q. Do the objections which you have spoken of as arising from the presence of the medullary rays apply to all exogenous vegetable growths, or to only a part of them?

A. I do not remember any exogenous growths that do not have medullary rays.

427 Q. How many of the exogenous woods have you tried for the purpose of making carbon filaments, and how extensively have been your experiments in that direction?

A. When I first started we made filaments of every thing that we could get hold of. I think we used as many as thirty or forty different woods of exogenous growths, but soon gave them up as hopeless, for the reasons I have already stated.

428 Q. Would an incandescent lamp having a fila-

ment made from wood of exogenous growth be, in your opinion, a practical lamp?

A. Not with any woods that I know of.

429 Q. As I understood you, in speaking of woods you mean exogenous vegetable growths?

A. Yes; that have medullary rays, or right angle fibres.

430 Q. How did you come to strike the idea of using bamboo?

Objected to by Mr, Kerr as incompetent.

A. We were carbonizing everything that we could get hold of, with the idea of getting a carbon that would give life under commercial conditions; and also which would give even manufacturing results; that is to say, one where we could made a thousands lamps, and not find that three or four hundred of them were spotted and useless, but an incandescing conductor, which in making a thousand lamps would be so perfect that only a small percentage would be bad and necessitate the uselessness of the lamp. I remember the circumstance about the bamboo. We had an ordinary palm leaf fan on one of the tables, and I was then investigating everything with a microscope, and I picked that up and found that it had a rim on the outside of bamboo cut from the outer edge, a very long strip. I gave this to one of my assistants and told him to cut it up and get out all the blanks he could from it and carbonize them, and put them in lamps, and run on the light current to ascertain their availability; and we were surprised to find that these lamps were several times better than any we had then succeeded in making. By a microscopic examination and by other experiments we ascertained the reason why; and I felt so convinced that we had got on the right track that after a short while I dispatched a man to Japan, as I have previously stated.

431 Q. What are the characteristics in bamboo which you have found to make it particularly suitable for your purpose.

A. I have already stated that the characteristic is

that the fibres run more nearly parallel in that species of wood than in any other, except in the one instance of this particular reed which I have stated we found up on the Amazon. Owing to this parallelism we are enabled to form a blank by cutting, in which the majority of all the fibres are parallel, and thus produce unspotted lamps; that is to say, lamps which, when brought up to a dull red, show an even degree of color. The contraction of the filament in carbonizing is also more homogeneous, due to the fact that the fibres are parallel and similar in character, and to the immense amount of resin as cellulose present in this species of material, the great advantage of which I have already recited.

432 Q. Is there any generic quality in vegetable fibres, because they are fibrous, which adapts them for the manufacture of carbons for electric lamps?

A. No; certainly not. They are rather a disadvantage. If bamboo grew solid, without fibres, but had the cellular formation just the same, I should consider it absolute perfection; and I have not the slightest doubt but what incandescent lamps would have a life at least six times longer than they have now. What is wanted is a cellular structure, even and homogeneous every direction, without fibres, but amorphous so to speak; that is to say, the same in all directions; so that on cutting it into shape it will have the same mass per unit section everywhere; and will on carbonization give the same amount of carbon; so that the carbon thus produced will have the same stress, like well annealed glass, throughout its whole body. The object of the cellular structure is to produce as a whole a filament in which the whole of the carbon is a continuous conductor of electricity, so that the whole of it takes part in performing the work; and by reason of the cellular structure its total resistance as a conductor will be great. Taking such a theoretically perfect filament of carbon (composed of carbon cells, with air spaces in each cell), the amount of investment in copper conductors will be in proportion to the amount of carbon in the filament. If the cells were filled solid, full of carbon, the investment in a station using such a lamp, covering a mile area of the City of New York, would probably be, say two hundred thousand dollars for the copper, whereas, if the cells were not filled solid, the investment would be, say one hundred thousand dollars; yet the economy and life of the lamp would practically be the same. The carbon in the interior of a filament is a positive disadvantage, because it does not give light, and requires a large investment in copper to carry the current necessary to keep it up to such a degree of incandescence as to permit the exterior of the carbon to emit light.

433 Q. Do I understand that out of the six thousand kinds of vegetable growths which you say you have tried, that the three or four which you have mentioned are the only ones having the proper cellular structure to make them suitable for incandescent lighting?

A. No; not exactly that; but none but these three or four that I have stated were sufficiently good for my purpose; that is, the production of a perfect commercial lamp and one easily and cheaply manufactured. Some of the inferior kinds of material could be used; and if, in the manufacture, those which were defective, as shown by bringing them up to a dull red, were thrown out, the residium would be commercial; but the percentage of good to bad lamps would be so enormously great (that is to say, the proportion of bad lamps would be infinitely greater than the good ones) that the cost would be prohibitory. Out of all these several thousand materials there are remarkably few that are of any value whatsoever.

434 Q. Have all vegetables fibrous growths a suitable cellular structure, with regard to the size and form of the cells, to make them adapted generally for the manufacture of conductors for incandescent lamps?

A. Oh, no. For instance, in pith the cells are so large that it is utterly useless. It seems, from the experiment, that the smaller the cells the greater will be the life of the conductor.

435 Q. How large a percentage of vegetable growths in your opinion, would have a cellular structure suitable for the manufacture of carbon filaments, which would make even fairly operative lamps?

A. I am not aware of the existence of an exogenous wood which would answer at all. The endogeneous (having parallel fibres) are the only ones that would be of any value; and these are not all capable of use. For instance, take the palm fibres. They seem to be of the same generic family as the fibres composing the bamboo; but the fundamental fibres of the visible fibres (but which can only be seen with a microscope) are very much greater in diameter in the palm than in the bamboo; and the cells of the charcoal are much larger in the palm than in the bamboo; so much so that our tests have shown that filaments cut from apparently perfect palm fibres did not give one fifth the life as corresponding bamboo fibres. There exists great diversity in endogenous woods in the amount of ash and silica between the fundamental fibres and of the fibre as a whole or the aggregated fibres; and this seems to produce some result in the chemical action or decomposition which takes place in carbonization. I have never been able to ascertain definitely what effect is produced; but it does produce an effect not desired, I know from experiments.

436 Q. Have you any patents covering the use of bamboo and similar fibres for this purpose which describe the proper way of cutting the material?

> Objected to by Mr. Kerr as immaterial and incompetent.

A. Yes, I have a patent on bamboo and similar fibre. It is No. 251,540, of December 27, 1881.

> A printed copy of the patent referred to is offered in evidence and marked "Defendant's Exhibit Edison Bamboo Patent, No. 251,540."

437 Q. What other materials besides carbonized fibrous material is used in the manufacture of filaments for commercial incandescent lamps?

A. One manufacturer makes a filament for carbonization by acting on hard twisted thread with sulphuric acid, to destroy its fibrous texture, and make it amorphous like, and continuously cemented throughout its mass. Another manufacturer takes films of collodiate, cut blanks for carbonization from the same, reduces the nitric acid from the compound by means of a reducing agent, thus making a non-fibrous structure which gives a very beautiful and perfect carbon filament. If its residium, which is transparent like glass, was as dense as bamboo, it would be as nearly theoretically perfect, in my mind, as any material that could be used for the purpose. Another maker, I believe, uses a solution of cellulose in sulphuric acid, reduced to a syrupy consistency and squirts it through a die into a chemical liquid which precipitates it as fast as it issues from the die, making a filament for carbonization, non-fibrous, but as the original cellulose can be regenerated, I believe that it does not alter the cells or destroy its properties to any great extent. Another maker uses a solution of melassic acid which he forces through a die. This is purely a chemical compound, artificially made. Another maker I have heard of, uses a chemical artificially made, which he squirts through a die into a solution which precipitates it. Other makers use bamboo. I think Sawyer & Man use bamboo, or at least did so at one time. The Siemens Brothers use the fibre of the agave, which I believe is of the same family as that of the fibre of the bamboo. Other makers have used silk thread twisted and treated by some chemical means to lock the fibres together, and render it, as a whole, non-fibrous, although not to the same extent as the use of collodion films.

The answer is objected to by Mr. Kerr as incompetent.

438 Q. Have you yourself made filaments from other than fibrous material; if so, state the facts?

A. Yes, I have made filaments from chemical combinations, compounds and mixtures, by squirting, by

flowing in sheets, by cutting therefrom, and in many other ways.

439 Q. When did you stop using paper in the construction of filaments for your electric lamp?

A. We only made a few hundred paper carbon filaments when we discovered the efficiency of bamboo, and made none after that discovery—that is to say, no paper carbons. We might have made a few, but only for experimental purposes.

440 Q. State approximately the date when you adopted bamboo, as nearly as you can now recollect it?

Objected to by Mr. Kerr as immaterial.

A. I think about January 30, 1880, or within a month of that.

441 Q. What defects, if any, in paper, caused you to discontinue its use for commercial purposes?

A. It did not give sufficient life; and if it was attempted to make filaments of high economy, the life was very short. Another difficulty was, that paper is so uneven. In the manufacture of paper, the pulp runs out on the wire cloth very unevenly. The fibres are not perfectly mixed, but some lie more in one direction than in another; and these vary. The paper was not always pure. It was loaded with different things. While the paper, after being calendered, seemed to be of the same thickness—really, before passing it through the calendar rolls it was very uneven in thickness. Passing it through the rolls pressed down the higher parts, and seemed to produce some harm to the texture. Another trouble was the cutting of these blanks from paper. It was very difficult to cut them even. Another defect was the carbonization, as the resulting carbon would be useless, since without the tarry matter which comes from the decomposition of the cellulose flowing in between the fibres, and on carbonizing locking them together, the paper could not be used. But fortunately, this tarry matter flowed while exuding from the decomposing cellulose between the fibres, and in carbonizing locked them together. It was enough to prevent cohesion between those kinds of carbons and the carbon of the cellulose. Great care was necessary to be exercised in causing the heat during the act of carbonization to be conducted equally and simultaneously to all parts of the decomposing cellulose, so that no one part should be decomposed before the other, as great contraction took place, and this would make a very unhomogeneous conductor (carbon being internally under great strain in various directions, like unannealed glass), and it also produces greater or less contraction in different parts of the resultant carbon, so that when put in a lamp and brought up to a red heat, some parts would be a dull red, and others would be a bright yellow, the filaments being destroyed at the hottest part. In fact, at the time that we used paper we found extreme difficulty in getting a great number of lamps free from spots so that they could be used; but when we got bamboo our troubles practically disappeared, as all these difficulties, or nearly all, were absent when bamboo was used.

442 Q. I call your attention to the original application for the patent in suit, which is contained in the Complainant's Exhibit File Wrapper and Contents. What was there, if anything, known generally in the art at the date of the filing of the application for the patent in suit, which was known as carbonized paper covered with powdered plumbago?

A. I never heard of carbonized paper covered with plumbago being used in the arts.

443 Q. Would the statement contained in that original specification, "We have tried carbonized paper covered with plumbago," be, in your opinion, a sufficient description to enable a person skilled in the art at the date of the application to make an incandescent conductor without further experiment.

A. If it is meant that the carbonized paper is rubbed over with plumbago, I think an expert skilled in the art could do it. It is not certain, from the description, if it was to be coated with plumbago before carbonization or after. I should infer that it was meant that

carbonized paper was rubbed over with plumbago. I do not exactly see what this would do.

444 Q. Assuming that the statement means to first fill paper, such as blotting paper, with powdered plumbago, and then passing a current through it to carbonize it, do you find a sufficient description in the specification to enable you to make a carbon in that way, without experiment?

Objected to by Mr. Kerr, that the specification speaks for itself.

A. I do not find anything in that specification that elucidates the meaning of the sentence about carbonized paper covered with plumbago. It does not state in the specification how it is to be used, but I infer that the paper was carbonized and then rubbed over with powdered plumbago. That is the nearest meaning that I can come to.

445 Q. In your opinion could a practical carbon for incandescent lamps be made by impregnating paper, such as blotting paper, with powdered plumbago, and then carbonizing it by passing an electric current through it?

A. Do you mean in a vacuum, or how?

446 Q. Either in vacuum, or air, or nitrogen, or illuminating gas?

A. My opinion is that it would require a great stretch of the imagination on the part of any expert skilled in the art, to conceive of a practical filament being made in this way. If you carbonize in vacuum there is never any carbon left in the paper. There is about forty-seven per cent. of carbon in paper, the balance being water, and the oxygen of the water is sufficient to burn up all the carbon.

447 Q. What would you understand by the expression "wood carbon or charcoal" contained in this original specification, considering, the same from the standpoint of the knowledge of those generally skilled in the art at the date of the application for the patent?

A. Charcoal from ordinary wood.

448 Q. Does that statement, in your opinion, give any information of value to others skilled in the art, which would enable them to make a practical incandescent lamp?

A. The paragraph states that they have tried three different kinds of carbon, but which is the best they do not state; and as everything depends on the kind of wood from which the wood carbon or charcoal is made, it would of course be necessary to ascertain by experiment the proper kind to use. I think a fuller description of incandescent conductors made from wood carbon or charcoal may be found in some of the earlier foreign patents of ten or fifteen years ago.

449 Q. What do you mean by charcoal from ordinary wood in your previous answer. Do you make any distinction between the species of the wood?

A. By "ordinary wood" I mean exogenous woods—woods of medullary rays, ordinary domestic woods.

450 Q. Was that the character of the charcoal generally known in the arts as charcoal, at the date of the filing of this specification?

A. Yes, sir.

451 Q. Do you find in this specification, or in the specification of the patent as issued, to which I also call your attention, any statement as to the selection of a particular wood or charcoal having suitable characteristics, or any description of necessary methods of cutting and preparing the fibrous material for carbonization?

A. The patent as issued seems to be very much expanded, in fact it is a somewhat fuller description of what was hinted at in the patent as first filed. I find that the patent of 1885 mentions carbonized paper, and drops the use of powdered plumbago, covering it, and it doesn't give any instructions of what wood to use to obtain the wood carbon, or any details as to precautions necessary to carbonize the same.

452 Q. The question also includes any suggestion as to methods of preparing it for carbonization?

A. I do not see any description either in the first or in the amplified application, explaining the methods of preparing the wood for carbonization.

453 Q. Does the original specification or the patent as issued, in your opinion, contain a sufficient description of the fibrous or textile carbon or original material from which it is made, the methods of preparing for carbonization, and the method of carbonization, to enable any person skilled in the art at the date of the filing of the application to make practical incandescent carbon for electric lamps?

A. The original specification indicates the use of three different incandescent conductors. It doesn't state which is the best. It gives no details as to manufacture, nor does it indicate the kind or quality of the paper or of the wood. It describes no means of putting them in shape for carbonization, nor any means of getting the ordinary gas carbon into shape, and the patent itself gives very little more details; in fact it leaves everything for experiment to determine the materials and operation best suited to produce a practical lamp.

454 Q. Please state specifically whether in your opinion the original specification or the patent as issued contains a sufficient description of the fibrous or textile carbon, its method of preparation, and the selection of material to enable a person skilled in the art to make a practical, fibrous or textile carbon for incandescent lamps?

A. Do you mean now in the present state of the art, or at the time the patent application was filed?

455 Q. I mean at the time the application was filed, and from the standpoint of information of those generally skilled in the art at that time.

A. Of course not. The patent would not indicate anything which has not been already indicated in other patents years before.

456 Q. That is, as I understand you, the patent in suit does not describe any advance in the art over what was before generally known?

Objected to by Mr. Kerr as incompetent.

A. No.

457 Q. Are all kinds of paper suitable for the making of incandescent conductors?

A. No.

458 Q. How many papers have you tried for that purpose?

A. I should say thirty different kinds of papers.

459 Q. What percentage approximately would you consider suitable for even a fairly operative lamp, and what percentage entirely useless for any kind of a lamp?

A. It depends on the maker. Some load their paper with so much China clay that you cannot use it; others make their paper but slightly different from makers of similar qualities of paper; some parchmentize their paper so as to destroy the fibrous nature of it; some produce a very even texture of paper, and other manufacturers produce a very uneven texture and then try to smooth it down by hard calendering. Paper is a very uncertain thing, and the same manufacturer will vary from time to time in the same brand.

460 Q. Do you know of any paper that would be entirely useless for the purpose?

A. Blotting paper, roofing paper, and glazed paper—that is to say, enameled paper.

461 Q. Do you find any statement in the original specification of the patent in suit, or the patent as issued, which shows how to select the paper for carbonization for the purpose?

A. No. It just says "paper;" that could be determined experimentally.

462 Q. As the art stood at the date of the application in the mind of those generally acquainted with the art at that time, would that have been a sufficient description to enable a proper paper to be selected without experiment?

A. No.

462½ Q. Do you find any statement in the original specification of the patent in suit, or in the patent as issued, which indicates whether the material is to be cut and shaped to size before carbonization or not?

A. There is nothing at all on this subject in the application, as filed. In the patent, as issued, it contains a description somewhat general, saying that the material is conformed to the desired shape and size, and then carbonized when confined in retorts in powdered carbon. It doesn't give any description of how it is to be cut.

463 Q. Is there any description in the original specification, or the patent as issued, with regard to the wood carbon, to show whether it is to be cut lengthwise of or across the fibers?

A. No; it gives no description.

464 Q. Would you consider thin Japanese, dental and rice paper as a suitable material to make an incandescent conductor from?

A. No.

464½ Q. Would it be entirely useless, or only partly so?

A. Useless.

465 Q. The complainant's expert, Mr. Pope, takes the position that the mention of the carbonized paper in the original specification is a sufficient statement to enable those skilled in the art to understand that the material is to be cut to size and shape before carbonization. Do you agree with him in this opinion?

A. The original specification calls for carbonized paper covered with plumbago. As it doesn't say whether the plumbago is to be put on the carbonized paper or on the paper before carbonization, I do not see as Mr. Pope's answer is relevant as applied to the original application as filed, while it might be so in the patent as issued; but I differ with him about the implication that it had to be cut to size before carbonization. I do not know that an expert would necessarily do that, because thick carbonized paper of the size implied in the sketch accompanying the application, could be cut out of the carbon itself. It is somewhat difficult for me, at this late date, to know what I would do at the date when the original application of Sawyer-Man was filed. I would probably have shaped it before carbonization, because I was already familiar, previous to that date, with carbonized paper in connection with incandescent lighting, telephones and their uses. If the patentees did cut the thing to shape before carbonization, why do they not fully set that out in the application so that it would not be requisite to call experts, at this date, to ascertain that fact?

466 Q. In your opinion, is the statement in the original application that the inventors have tried carbonized paper covered with plumbago any indication to those skilled in the art as to whether the wood carbon or charcoal is to be cut to shape before or after carbonization?

A. No indication that the wood carbon is to be formed out of wood previous to carbonization.

467 Q. Look at the drawings of the patent in suit. What, in your opinion, would be the advantage, if any, in using a carbon from fibrous or textile material in such a lamp?

A. The lamp shown is one only suitable for working in a series and not in multiple arc. It is constructed to work in a series where large currents are necessary. In lamps of this kind of a system the endeavor is to diminish the resistance of the incandescing conductor as far as possible in contradiction to multiple arc systems where the object is to increase the resistance of the incandescing conductor as far as possible. The ordinary gas carbon is suited to the lamp of the patent of 1885 on account of its low resistance. The use of an incandescent conductor of carbonized paper is taking a contra direction to what is necessary. This only defeats the great object to be attained—that is to say, low resistance, as the carbon residium from the carbonization of paper being porous, has per square millimeter a very much greater specific resistance than gas retort carbons; but, of course, if the carbonized paper was not used, but the carbonized paper coated with plumbago or impregnated with plumbago by some means, and carbonized, as is indicated in the application as originally filed, the resistance of the incandescing conductor might be got down quite low and possibly utilized. But using all carbonized paper alone in a lamp

of this character, suitable only for a series system, makes the patent very ambiguous, and the rationale, taken from a scientific standpoint, would probably puzzle any expert not acquainted with the exigencies of the patentees in amending the application.

468 Q. Would there be any difficulty in making a carbon of the size and shape shown in the patent in suit from a hard carbon mixture such as Carré used in making his pencils?

A. No difficulty; that would be an easy matter, as their manufacture was well known.

469 Q. Would such a carbon made from a hard carbon mixture such as Carré used be suitable for a lamp of the construction shown in the patent in suit; and what would be its value in such a lamp compared with the fibrous carbon?

A. It would be better than paper, but not so good as bamboo.

470 Q. Would it be better than ordinary charcoal, such as would be known by the expression "wood carbon or charcoal," at the date of the filing of the application for the patent in suit?

A. My impression is that it would be better than ordinary wood charcoal from domestic woods.

471 Q. How much of a test as to the capacity of an incandescent electric lamp would it be necessary to make in order to arrive at any certain conclusion as to its practical or commercial character?

A. For two or three years, in our test-room at the lamp factory, we were in the habit of checking our experimental results as to the efficiency of any change in the methods of carbonization, or materials, or ortherwise, by setting up ten lamps at five times the normal candle power which they would burn in practice to determine the results of such experiments in terms of lamp life; but we found, after an enormous number of experiments, that the results, based on such a small number as ten lamps were, in a great many cases, utterly fallacious, and we arrived at the conclusion, by experiments of lamps of definite character (and also mathematically), that no results of an experiment could be predicated upon any less number of lamps on a full test than fifty; and where great certainty was requisite, one hundred lamps are employed by us. For instance, I have now two sets of one hundred lamps each in my laboratory, which have been running, if I remember rightly, nearly a year at normal incandescence, to determine experimentally whether the multiplied factor of lamps set up at five times their normal, is a correct one. To the end that we may reach quicker results, for instance, if it was desired to ascertain the efficiency of a peculiar quality of a new material which some of my men had sent in from outlying countries, we would make up fifty lamps, put them on a life test at eighty candles (instead of 16, at which they would be used in practice), and we would arrive quickly at the average life of the whole, because the lamps at this high temperature did not last very long; and we would from the average life of these lamps determine their relative value as compared to another and similar set of lamps made from another material; and also determine what their life would be if run at sixteen candles in place of eighty, from an empirical law which we had established from our experiments. The lamps which I have referred to as set up in my laboratory, and which have been running nearly a year, are to determine the correctness of the formula as to the lasting powers of a lamp at sixteen candles, which would have a given life if set up at eighty candles.

472 Q. Would the fact that a single lamp ran for many hours be even a reasonable indication, in your opinion, that the carbon in the lamp was made of proper material and under the proper conditions for the general manufacture of a commercial lamp?

A. No result can be obtained from one lamp. If the aveage life of one thousand lamps is two thousand hours and they are all set up at sixteen candles, three or four will be destroyed in the first two hours, and they will follow along one after the other over a period of six thousand or seven thousand hours, but the average of the whole would be, say two thousand hours.

473 Q. What do you understand is the meaning, in the art, of a "lamp chamber made wholly or entirely of glass and hermetically sealed?"

A. In incandescent lighting it means wholly of glass and all joints in the act of manufacture being sealed by fusing the glass. Hermetically sealed, as applied to the modern art of incandescent lighting, has probably a different meaning than when applied to canning fruit and such things. Hermetically sealed means sealed in such a way that it maintains its vacuum continuously for any length of time. I know of no means whereby this hermetical sealing for preserving a continuous vacuum can be done except by a fusion of the glass, the chamber being made wholly of glass, through which the platinum electrodes, having the same coefficient of expansion, pass. A chamber made wholly of glass might be made in two parts and ground together; but this would not maintain a vacuum, if some wax or similar material was put into the joint, in a fruit-jar sense, it would be hermetically sealed, but not in the sense as applied to modern incandescent lighting, where, owing to the extreme minuteness of the incandescent conductor and the quantity of carbon, an extremely stable vacuum must be continuously maintained. It was the very fact that I could not maintain my vacuum which prevented me from continuing the experiments right along, in the endeavor to make a multiple arc lamp with a filament of carbon of high resistance.

In endeavoring to get a high-resistance lamp by the use of platinum, coiled, I arrived at conditions gradually wherein I was enabled to get an inclosing globe entirely of glass, all fused together, through which the platinum wires passed. Arriving at these conditions, I resumed experiments on the use of carbon, knowing that I had a chamber which would preserve a vacuum continuously. The old style of obtaining a vacuum was so crude, as compared with the modern method, that not only could not a sufficient degree of exhaustion of the air be obtained, but even with the exhaution obtained, it was not continuous, owing to the leakage at the joints of the apparatus.

474 Q. What do you mean by the statement that the old means of obtaining a vacuum were so crude as compared with the modern?

A. I mean the mechanical air pump and bell jar, and Gassoit cascade and other devices.

475 Q. As I understand you, then, you did not consider it necessary, for the purpose of increasing your information, to make further experiments with carbon until you had produced such a vacuum chamber?

A. No. It was the conditions that I desired and once I saw that I had reached the conditions experimentally, and had proved that a chamber made entirely of glass, by fusion, through which the platinum wires passed maintained a stable vacuum, I saw at once that it would be possible to make a lamp of high resistance from carbon. In my early experiments with platinum lamps, the thing I desired is therein detailed, to wit, a lamp which as a whole would give high resistance when giving the ordinary unit of light, that is, sixteen candles, so as to permit its being used in the multiple arc system of distribution. I had known for a long time, and knew in 1877, that carbon had the requisite resistance to afford a very simple conductor to accomplish the object; but I also knew in 1877 that it would have to be made hair-like; and as my results showed that carbons which were far from hair-like, but many times larger in bulk approximately, were soon destroyed by my not being able to get sufficient vacuum to maintain the same, I knew that it would be useless to try a filament which would have the qualities I desired under such adverse conditions. But the moment that I had got apparatus and means and methods whereby I made a chamber wholly of glass, and with the McLeod guage on the Sprengle pump had determined that it held a vacuum continuously, I knew that I could make the hair-like filament permanent, provided the filament itself could be made sufficiently homogeneous.

476 Q. To your knowledge, are there any incandescent lamps now sold in which the atmosphere is either of nitrogen or of hydrogen?

A. None sold. The art has so advanced that the experts now know that with an electric current of one horse power, giving eight lamps of sixteen candles, each per horse power, when the filament was in a vacuum, the same lamps would not give more than one lamp per horse power, or sixteen candles, when nitrogen was in the globe at the atmospheric pressure; and would give no light at all if hydrogen was in the globe at the atmospheric pressure. In other words, if eight lamps, each giving sixteen candles, run by one horse power of electricity, the chambers of which lamps were highly exhausted (that is to say, a vacuum) and so arranged that hydrogen could be let into each of the chambers, so that the same should be at atmospheric pressure, and then sealed, the filament would go down to a dull red, and practically give no light at all, the whole of the heat being carried to the chamber, and radiated by conduction and convection, and not by radiation as in a vacuum. It is a most absurd thing to use nitrogen or hydrogen.

The further examination of the witness is adjourned to March 7th, 1889, at 11 A. M., at the same place.

Consolidated Electric Light Co.

against

McKeesport Light Co.

Orange, N. J., March 7, 1889.

Met pursuant to adjournment.

Present—Messrs. Walter K. Griffin and Richard N. Dyer, for defendant; and Mr. Thomas B. Kerr, for complainant.

The witness, Thomas A. Edison, being further examined by Mr. Dyer, testifies as follows:

477 Q. Referring to Figure 5 of the patent in suit, do you consider that it would be practically possible or feasible to secure a glass plate y to the flange x by the fusion of the two glass parts together? Please state your reason for any opinion you may express.

A. I suppose that it would be possible, as an illustration of how expert a glassblower may be in the manipulation of glass; but I do not think it would be capable of being brought to a commercial operation. If it were to be done, of course it would not be necessary to grind the two faces perfectly together; and if intended to be sealed by fusion of the glass of course it would be made different than as shown in the patent. But taking the Figure 5 of the patent as the real size, it would be rather difficult, and the difficulty would increase with the increase in the size of the lamp. I do not see how the metal tubes which pass through the two holes in the glass plate y could be sealed in very well, except they were of platinum (which I do not understand they were), and even if they were of platinum my impression is that owing to their great size they would crack the plate on cooling. Of course, if the lamp had ever been intended to be sealed by fusing the glass together it would not by any possible stretch of imagination have been made as set forth in Figure 5.

478 Q. Again calling your attention to Figure 5 of the patent in suit, and also calling your attention to the Sawyer-Man Patent No. 205,144, to which reference is made in the patent in suit, and which explains how the metal tubes are to be closed by the metal caps screwed over their ends, please state whether or not in your opinion a lamp-chamber could be closed in this way so as to maintain a vacuum which would be suitable for a practical incandescent lamp?

A. No, this is a ground-joint seal. The caps as shown in Figure 5 would have to contain some unctious substance, the same as described in their patents, to maintain a vacuum for an hour even.

479 Q. Even by using the unctious or other sealing substance, would the caps in your judgment be capable of maintaining a suitable vacuum?

A. I have testified several times that chambers in which it is proposed to maintain a vacuum, made of two parts ground together, with or without some cement or mobile substance, will not maintain a continuous vacuum, and is not a hermetical sealing which meets the requirements of the modern incandescent lamp. Such chambers will not hold a vacuum. Such lamps will not be useful, or commercially made with such chambers. I know of no such lamps which were ever commercial or which were ever introduced; and I do not think there is any such lamp now being made, sold, or used, with chambers of this character, with the air exhausted therefrom. This answer will cover any of the chambers or devices shown in the patents of Sawyer & Man, 205,144 and 317,676.

480 Q. Please state approximately, if you know, when the complainant, the Consolidated Electric Light Company, began the business of incandescent electric lighting?

A. I am not very familiar with the various organizations through which the Consolidated Company was formed; but if I remember rightly they bought or consolidated with a company called the American Electric Light Company, whose technical department (that is to say, the making of lamps) was conducted by experts taken from my factory and laboratory; and if my memory serves me rightly it was these experiments which started the lamp factory of the Consolidated Company, and I think they went into the business for the sale of lamps about a year and a half or two years after we had started in business.

Mr. Kerr objects to the last sentence of the answer as incompetent.

481 Q. What company do you refer to as starting in the lamp business a year and a half or two years after your company had started to make and sell lamps?

A. I refer to the Consolidated Company, which had acquired the American Company.

482 Q. Have you ever examined any of the lamps

made by the Consolidated Company? If so, please state when, and also state the result of your examination with regard to the construction of the lamps?

Objected to by Mr. Kerr as incompetent and immaterial.

A. I have examined the lamps sold by the Consolidated Company, which lamps were known as Sawyer-Man lamps. They were almost precisely the same as our own lamps. The carbon filament was made of bamboo, which fact I ascertained from a microscopic examination. The only difference in the carbon was that it was "flashed" by the deposition of carbon on the surface of the original filament. I think this examination took place about two years or two years and a half ago.

483 Q. How many lamps did you examine at that time?

A. About three.

484 Q. How were the lamp-chambers of those lamps constructed?

A. The chamber was made entirely of glass, by the joints being fused, and the small platinum wires sealed in the glass, and passing into the chamber, just as is shown in my patent No. 223,898.

485 Q. What was the condition of the art of electric lighting when you commenced your experiments; and what generally was the advance made by you in such art—excluding any considerations as to the quality and production of suitable carbons. Please state this so that the Court can understand the adjuncts necessary to a successful lamp in order to produce a complete system of electric lighting?

A. In 1878, when I took up actively the subject of electric lighting, no apparatus had been devised, so far as I know, that would in any measure fulfill the conditions which I thought would be necessary to make electric light suitable for the illumination of interiors. In that year was begun the introduction in Paris of the Jablochkoff candle, and a year or so later the introduction of the arc lamp was begun in this country. These electric lights were of very large candle power, each unit being of several hundred candles, and I did not think them suitable for general interior illumination. The subdivision of the electric light into small units comparable with that of the ordinary gas jet was what I thought was required. The general scientific opinion was that this could not be done. Even after it had been announced in the public press in 1879, that it had been accomplished by me, the statement was discredited and was pronounced by many eminent scientific men, both in this country and abroad, to be an impossibility. A committee was appointed by the English Parliament to examine into the general subject, and they called before them as witnesses nearly all of the prominent scientific men in England, all of whom, with the single exception of Mr. Tyndall, testified that, in their opinion, the sub-division of the electric light was an impossibility. Mr. Tyndall said he would hardly go as far as that—he would not say it was impossible, but he would not like to undertake the solution of the problem.

It is true that incandescent electric lamps had been proposed more than a quarter of a century previous to my taking the subject up, but no material advance had been made in their production, and the correct principle upon which to build them had not been, so far as I know, discovered. Not only had no incandescent lamp been made that was capable of practical use, but the conditions of use of a practical lamp had not been predetermined, nor had any comprehensive system been devised, whereby practical lamps of small unit candle power could be used to supplant gas as a general illuminant. It was not only necessary that the lamps should give light and the dynamos generate current, but the lamps must be adapted to the current of the dynamos, and the dynamos must be constructed to give the character of current required by the lamps, and likewise all parts of the system must be constructed with reference to all other parts, since, in one sense, all the parts form one machine, and the connections between the parts being electrical instead of mechanical. Like any other machine the failure of one part to co-operate properly with the other part disorganizes the whole and renders it inoperative for the purpose intended.

The problem then that I undertook to solve was stated generally, the production of the multifarious apparatus, methods and devices, each adapted for use with every other, and all forming a comprehensive system whereby electricity properly controlled and directed could be distributed over large areas through the streets of a city, and supplied to houses in which it would feed incandescent electric lamps of moderate candle power, which would be entirely under the control of the householder, the whole to be on the same scale as the present system of gas distribution and affording the same character of convenience to the users.

The first thing necessary to be done was to adopt a fundamentally correct system of distributing the electric current, and then to devise which could be worked practically on such a system that would be practical and satisfactory both in a commercial and scientific sense. The essentials of a comprehensive system of electric illumination, similar to the general plan of illumination by gas, were a network of conductors all connected together, so that in a city area the lights could be fed with electricity from several directions, thus eliminating the disturbances to any particular section.

Second. To devise an electric lamp which would give about the same amount of light as the gas jet, which custom had proved was a suitable and useful unit, and which should possess the qualities necessitated by small investment in the copper conductors. It was also necessary that each lamp should be independent of every other lamp, although on the same circuit. That the light should be produced sufficiently economically to commercially compete with gas. That the lamp should be durable and capable of being handled by the public and cheap to manufacture, and one that would remain incandescent and stable a great length of time.

Third. It was also necessary to devise means whereby the amount of light furnished a consumer would be accurately determined, as in the case of a gas meter, and that this should be done cheaply and reliably.

Fourth. I had also to devise a system of conductors capable of being placed underground or overhead, and which would allow of being tapped at intervals, speaking generally, about the width of each house facing the street—so that service wires could be run from the main conductor into each house, as gas pipes run from gas mains, and generally whatever was necessary to such a comprehensive system of distribution as the system I had in view required. Where the conductors were to be placed underground, which I contemplated doing in large cities, it was necessary to devise a system of protective pipes for the copper conductors, which would allow of their being tapped wherever required; also manholes, junction boxes, connections, and the various paraphernalia of a complete system for underground general distribution.

Fifth. I had also to devise means of producing at all points, and on an extended area of distribution, a practically even pressure analogus to gas, so that all of the lights should give an equal light at all times and independent of the number that might be in use. I had also to devise means for regulating, at the point where the current was generated, the quality of the pressure of the current throughout the whole lighting area, also a means of indicating what the pressure was at the various points of the area.

Sixth. I had also to devise economical dynamo machines for the conversion of steam power into electricity, means for connecting, disconnecting, working and regulating the same; means for equalizing their loads; means for regulating the number of machines to be used to the demands on the station for electricty from the users of the light. The arranging of complete stations, with steam power and electric apparatus, and devices of all kinds to suit the varying conditions of buildings available for such stations in cities.

Seventh. I had also to devise devices which would prevent the current used from becoming excessive upon any conductors and causing fire or other injury, switches whereby the current could be turned on or off, at such points as it was desirable that this should be done, lamp holders, electric chandeliers and the like. I had also to devise means and methods for placing the wires that were to convey the current to the chandeliers in buildings.

I set out to found an entirely new industry and art. My system contemplated the generation of electric current on a very large scale, and its distribution throughout an extended area, and the division and subdivision of the current into small units converted into light at innumerable points in every possible direction from the point of its generation. Nothing of this character had ever been undertaken before, and the accomplishment of this result presented at almost every point problems of the utmost difficulty, the solution of which was not suggested by anything that had gone before in the art, but required a great amount of experiment and labor.

486 Q. What, in general, was the history of the commercial introduction of the Edison System of Electric Lighting?

A. I entered into relations with the Edison Electric Light Company in the fall of the year 1878, under an agreement by which I was to perfect the system I had in contemplation. I had at the time a large laboratory and a machine shop at Menlo Park, New Jersey. I immediately increased the working force in my laboratory and machine shop, employing mathematicians and scientists as well as the best mechanical skill, and I commenced experimenting on an extended scale, having at one time upwards of one hundred men engaged upon various branches of the experimental work. In December, 1879, I gave a public exhibition at Menlo Park of my system, lighting up the grounds and buildings with my carbon filament lamps, which I had then brought to what I considered commercial perfection.

By reason of the obstacles which are usually met with in the establishment of an entirely new art, the

introduction of my apparatus proceeded slowly at first. The company did more or less business in the way of selling isolating plants for lighting single buildings, but it was not until the fall of 1882 that a complete central station was in operation. This plant was a great undertaking for an initial plant. Its conductors were designed to supply current to 16,000 lamps. They were laid underground in the streets in the lower part of New York City, and extended through all the streets of a district about one square mile, bounded on the east by the East River, on the south by Wall street, on the west by Nassau street, and the north by Spruce street, Ferry street and Peck Slip. The engines and dynamos for generating the current were located in a building on Pearl street. The first cost of this plant was in the neighborhood of $600,000. Since the erection of the first central station plant a large number have been installed by the Edison Light Company and its agents.

487 Q. What, if anything, did you do in the way of establishing factories for the manufacture of your electric lighting apparatus?

A. There was no established factories at the time which could undertake the manufacture of the apparatus. The necessity of establishing factories, together with the inventing and devising of the numerous tools and methods of manufacture, and the education of men in the manufacture of new character of apparatus, was a cause of great delay in the introduction of my system. The experimental work had been carried on in my laboratory and machine shop at Menlo Park until 1880, when I established works for making lamps. I had to establish these works, as it would have been impossible for me to have had the lamps made in any established factory, nor was there any skilled class of labor which could have made such lamps without my personal instruction or the instruction of my assistants. Shortly after the establishment of my lamp factory I caused the establishment of Bergmann & Co., for the manufacture of lamp sockets, meters, switches, safety catches and the various small parts required in electric light plants, as well as chandeliers, brackets and others forms of fixtures for supporting the lamps. These could not have been made in the general market for the reasons previously stated. Shortly afterwards the Edison Machine Works was established for manufacturing dynamo machines. This factory I had to establish for the same reasons as above stated. I also formed the Electric Tube Works, which has since become amalgamated with the Edison Machine Works for manufacturing underground conductors. These factories I put up largely at my own expense, investing all the moneys I had made from my previous inventions, and to-day I own a controlling interest in them. I established them because the business could not have been developed without them, and placed over each, as general superintendent, gentlemen who had been connected with me in my laboratory, and who were familiar with the patented devises of my system.

488 Q. Did you or the Edison Electric Light Company have any trouble in finding skilled men to install these central station plants?

A. As I have said the art was an entirely new one. This made it necessary that men should be specially educated in it. There were no body of skilled artisans from which the company could draw. All the work had to be done at first under the direct supervision of myself and my laboratory assistants, who had acquired a knowledge of the inventions and apparatus used in my system during the course of my experimental work. In the installation of the first central station plant in New York City I was almost constantly present, giving my entire time to the work day and night. I had to give my careful and constant supervision. In illustration of what I say, I will state that I actually worked in trenches in the streets in the lower part of the city, in which the conductors were being laid, making many of the connections myself.

After the first station had been built the public were to form companies and install my system. The great difficulty was in getting men to do the work. There were not then, as now, electrical engineers who were familiar with my work and who could be employed for

the actual construction of a central station. The art was new and men had to be educated and I had to educate them. I was compelled to form a construction department and personally undertake the construction and installation of central station plants in cases where my company had made contracts for the erection of plants. I gave this construction department my personal attention giving up my experimental work to a great degree. I gathered around me a body of men whom I instructed in the details of my system. In the shops I established training departments, so that the men I employed could become familiar with the apparatus that was to be used and generally familiar with all arrangements of the business, to the end that they might become able to superintend the installation of plants. I expended some $54,000 of my own money in educating men in my construction department and in my shops, so as to develop the company's business, for which I have never received the slightest return. Many of the persons whom I instructed, after they had acquired knowledge of my system left my employ and used the knowledge they had acquired against my interest and the interests of my company.

Counsel for complainant objects to so much of the deposition of this witness as relates to the manufacture and sale of lamps subsequent to the date of the application for the patents in suit, or subsequent to the date when the witness or the Edison Electric Light Company had notice of the rights of Sawyer-Man, as incompetent and immaterial. Counsel also makes the same objection to the answers to questions 485, 486, 487 and 488. These objections are entered at this point in the examination by agreement of counsel, and are here made for the purpose of saving interruption and loss of time during the progress of the examination.

Cross-examination by Mr. Kerr (without waiver of objection):

488 x-Q. When was the Edison Electric Light Company formed?

A. I see by looking at a copy of the certificate of incorporation that the company was incorporated 1878.

489 x-Q. How soon after the formation of the company did you begin your work on incandescent lamps, which you speak of as having resulted in the production of a successful lamp?

A. I was experimenting on devising a system of electric lighting before the company was formed, and continued these experiments right along until I had reached a successful lamp.

490 x-Q. What facilities, as to men, money and apparatus, did you have in connection with your lamp work at that time?

A. What time?

491 x-Q. The time referred to in the last answer?

A. I said that I had experimented to devise a system of electric lighting before the Edison Electric Light Company was formed, but did not state any time.

492 x-Q. My question referred particularly to your work after the formation of the company. I repeat the question with that understanding. What facilities, as to men, money and apparatus, did you have in connection with your lamp work at that time?

A. I had a laboratory at Menlo Park; I had sufficient money for all experimental purposes, but the facilities were gradually augmented after the formation of the company until I had all that was required.

493 x-Q. My question also involved men?

A. I had all the men that I required.

494 x-Q. Please name some of the men you had assisting you in these experiments?

A. Charles Batchelor, Francis R. Upton, Francis Jehl, John Kruesi, Martin Force, W. J. Hammer, Ludwig Boehm, Crosby and others.

495 x-Q. Were you limited in any way as to expenditures, or the employment of men, or the purchase of apparatus, or any other thing that might be of advantage in your work?

A. No, not after the formation of the company.

496 x-Q. Please give me the names of the persons who constituted the company?

A. The incorporators, as shown by the certificates, were

497 x-Q. What relation did Mr. Lowrey have to the company during the year 1879?

A. He was a director, and I believe, the counsel of the company.

498 x-Q. What was the capital of the company?

A. I think the first capital was $300,000.

499 x-Q. If it was subsequently increased please state that fact, and also what, and as near as you can when the increase was?

A. I remember that it was afterwards increased to, I think, $700,000, and then again to $1,500,000. I have no means of refreshing my recollection, and cannot give the dates when these increases took place. I did not pay much attention to that branch of the subject.

500 x-Q. What was the par value of that stock?

A. $100.

501 x-Q. Do you know what its market value in 1880, 1881 and 188 . was?

A. I considered the intrinsic value to be about $500 a share. The market value was very variable. I did not sell any of my own stock, and therefore cannot state the prices at which sales were made, except from hearsay.

503 x-Q. Isn't it a fact that it went up to about $1,250 a share during that time?

A. My information was that it sold for that.

503 x-Q. Who were the financial agents of the company during 1879 and up to 1883. I mean the bankers?

A. I don't remember who the bankers were. The firm of Drexel, Morgan & Co. were interested as stockholders, and one of the members of the firm was a director.

504 x-Q. I wish you would just give his name?

A. Egisto P. Fabri. I don't think they were the bankers.

505 x-Q. What variety of bamboo is it that you say you use in the manufacture of lamp carbons?

A. A variety which grows and is extensively cultivated in Japan for artistic purposes.

506 x-Q. I wish that you would give the name of the variety, and from what part of Japan it comes, so that it may be identified?

A. I think the name of the quality which is the best is called Matake. It is, however, the same quality as is used in Japanese art work, having a very polished yellow surface. Flexible screens, lattice like, put together with thread, and sold in Japanese art stores in New York, are made of the character of bamboo that we use.

507 x-Q. Referring now to the patent in suit. Do I understand you that it would be impossible to make a lamp, such as is shown and described there, and fill it with nitrogen gas, that would be a practical lamp?

A. Yes, for commercial purposes.

508 x-Q. What is necessary to fit a lamp for commercial purposes—I mean what qualities?

A. That it should be sufficiently economical, in the production of light, to permit of competition with gas, when an equivalent amought of light from an electric light can be sold for 50 per cent. more than the same amount of light by gas; it also must be cheap; that is to say, the lamp must be cheap to manufacture, simple, not liable to get out of order; the filament should last a considerable length of time, and generally have such characteristics as would permit the use of a moderate investment in the distributing system in streets and houses upon which it is to be worked. The use of nitrogen, at atmospheric pressure, would permit the use of the carbon conductor in a lamp longer than in a vacuum, as the tendency to leakage through the joints would not be so great. But, on the other hand, the employment of this means brings in a factor as disadvantageous, commercially speaking, almost as the shortened life of the conductor due to an unstable vacuum. As I have already testified, under these conditions of burning in nitrogen gas at atmospheric pressure, we would obtain only about one-eighth as much light from any incandescent conductor as would be obtained from the same in high vacuo with the same amount of electricity.

509 x-Q. Could you take the patent in suit, make a lamp like it, fill it with nitrogen gas, and, by the application of a proper current, bring the carbon to incandescence?

A. Yes, sir.

510 x-Q. Could you make such a lamp last for a day?

A. I don't think so.

511 x-Q. Do you think it would be impossible?

A. It would depend upon the degree of incandescence. If brought up to the same degree of incandescence as the ordinary incandescent lamp now used, I do not think it would last a day.

512 x-Q. What do you mean by the ordinary incandescent lamp?

A. I mean the regular incandescent lamp now sold throughout the country as under my patent 223,898.

513 x-Q. What is the candle power?

A. A degree of incandescence of about 240 candles per electrical horse-power.

514 x-Q. Suppose such a lamp to be burned at 25-candle power, do you think you could make one which would last for a day?

A. Not at the specific incandescence of 240 candles per horse-power.

515 x-Q. I have called your attention to the lamp shown by the patent in suit. Please state whether you think it is impossible to make a lamp like that, having a burner composed of fibrous or textile carbon, which would burn at the brilliancy of an ordinary incandescent lamp of the present day, for a period of 24 hours?

A. I do not believe it could be made to do so.

516 x-Q. I now show you a printed book entitled

"In the United States Patent Office. Edison vs. Maxim vs. Swan. Interference Electric lamps. Testimony in behalf of Edison." Please state whether you testified in that interference case, and whether your deposition appears on pages 1 to 13 and pages 164 to 252?

A. Yes, sir.

517 x-Q. Do you know that this is the paper book containing the printed testimony on your behalf in that interference?

A. It appears to be. I have no doubt but what it is.

> The Examiner is requested to mark the paper book for identification as "Complainant's Exhibit Edison, Maxim and Swan. Interference Record." The Examiner does so."
>
> The Exhibit is objected to by counsel for the defendant as being incompetent and irrelevant, and as being only a part of a record.

RE-DIRECT EXAMINATION BY MR. DYER:

518 Re-d. Q. In what sense, if at all, in your opinion, would the lamp described and illustrated in the patent in suit be practical when constructed with the general knowledge of the art as it existed at the date of the application, namely, January 9, 1880?

A. It would not be a practical lamp at the time of the filing of the application. Neither would it be a practical lamp if made according to the amended specification and the drawings; and I have testified that, if made according to the specifications and drawings, it is not a practical lamp now.

517 Re-d. Q. To what extent would such a lamp be capable of use if constructed with the general knowledge of the art as it existed at the date of the application?

A. No use.

520 Re-d. Q. Has the general knowledge of the state of the art materially increased since the date of the filing of the application of the patent in suit?

A. Yes, sir; the general appreciation of the problems inherent in the practical part of the art has been greatly acquired by experts since the application in question.

RE-CROSS-EXAMINATION BY MR. KERR:

521 Re-x-Q. State whether an incandescing conductor for an incandescent electric lamp, composed of carbonized fibrous or textile material, and of an arch or horse—shoe shape, is a practical thing?

A. It depends on the nature of the material from which the incandescent conductor is made, and the conditions under which the same is worked.

522 Re-x-Q. Suppose that material to be paper?

A. It depends on the kind of paper, the method of carbonizing, and the conditions under which it works.

523 Re-x-Q. Those things all given, namely, a proper kind of paper, proper carbonization, and proper conditions under which it is worked, such a conductor would be a practical and operative thing, would it not?

A. It would be a relatively practical success as compared with bamboo; but in one sense, that is to say, for competing purposes, it could not compete with bamboo for the selling of light from lamps constructed as stated. The lamps, in their manufacture, would be under the disadvantage that not as many given lamps from a given lot can be obtained from the use of paper as from the use of a more perfect material such as bamboo, and the life of the lamps would not be so great as those containing bamboo?

524 Re-x-Q. You did not know that fact on January 9, 1880, did you?

A. No, I did not. The paper lamp was the best one we had at that time when made in quantities, although I might have tried experiments on other material which showed in one or two cases better than paper. I don't remember now, as I have not read over my previous testimony, and it is so many years ago that I have a very indistinct recollection and would not be able to answer this question accurately without refreshing my memory by reading over testimony I have already given and looking at my original sketches.

525 Re-x-Q. Was your first bamboo lamp as perfect as the lamp you now make?

A. No, not quite so perfect.

526 Re-x-Q. There has been an advance then in that particular with yourself, has there not?

A. Yes, sir; we are enabled, by careful manipulation in the various processes in the factory, to produce lamps which, as a whole, are much better than we were able to make, producing the same number in 1880, although some of the 1880 lamps were far superior to some of the lamps now made from the same material.

527 Re-x-Q. You are constantly improving the character of your lamps, are you not?

A. Yes, sir, constantly improving on the details of manufacture so as to ensure against the production of a greater number of lamps in which defects are absent.

528 Re-x-Q. You are also improving their efficiency, are you not?

A. The efficiency is improved by the perfecting of the details of manufacture.

529 Re-x-Q. Isn't it a fact that the art of manufacturing incandescent lamps is constantly improving?

A. The art of manufacturing is constantly improving in the sense that in a lot of 100 lamps there will be a less number broken in the first hundred hours than in a lot of 100 made the year previous.

530 Re-x-Q. And also that there will be a greater number of good lamps?

A. Yes, sir.

531 Re-x-Q. Is the combination of an electric circuit and an incandescing conductor of carbonized fibrous material included in and forming part of said circuit, and a transparent hermetically sealed chamber in which the conductor is enclosed a practical and operative combination?

A. If the incandescent conductor of textile or fibrous material is a good one and made from proper material and properly carbonized and properly exhausted, and the chamber is absolutely hermetically sealed by the fusion of the glass so that the whole of the chamber shall be made of glass through which the platinum wires are sealed, and the vacuum is high and stable, such a lamp would be, if included in an electric circuit, a commercial success.

532 Re-x-Q. If you had made such a lamp and had found that the conductor was destroyed by reason of defective sealing of the chamber, what would you have done?

A. I would have done just as I did in my Patent 223,898, make the chamber entirely of glass by fusion—hermetically seal it in reality and not in name.

533 Re-x-Q. In short, you would have made the sealing perfect, would you not?

A. Yes, sir.

534 Re-x-Q. That would be the obvious thing to do, would it not?

A. Not obvious, no. It took me a long while to reach, by experimentation, the condition which caused me to appreciate that fact.

535 Re-x-Q. My question supposed that you appreciated the fact that the sealing of the lamp was defective. Having appreciated that fact, was it not the obvious thing to do to make that sealing perfect?

A. I appreciated the fact that the method shown in the patent of the complainant was defective, but I did not appreciate the fact until I had experimentally determined that the only possible means whereby a continuously stable vacuum could be obtained was by the use of a chamber made entirely of glass, and when this became certain to my knowledge I applied for the Patent No. 223,898.

536 Re-x-Q. I didn't say anything about the complainant's patent. My question supposed a lamp having an electric circuit, an incandescent conductor of carbonized fibrous material included in and forming part of the circuit, and a transparent hermetically sealed chamber in which the conductor was enclosed, and the appreciation of the fact on your part that the sealing of such a lamp was defective, and I asked you whether

it was not the obvious thing to do for you to make that sealing perfect. Now, was it not?

A. Your question implies that it was hermetically sealed. If it was hermetically sealed there would have been no use of fusion; but in point of fact such lamps as are implied by your question are not hermetically sealed. It was not obvious at the time—at least it was not to me—that by fusion of the glass such a chamber would maintain a stable vacuum. Such things are never obvious. For instance, the telephone and the phonograph—two excessively simple things, performing great results—were not obvious to men well skilled in the art, who knew all the conditions necessary to produce such instruments. In science those things which are the most simple and most conspicuous seem to be hidden the longest. Their very conspicuousness seems to hide them.

537 Re-x-Q. We will omit the word "hermetically," and I call your attention to the fact that I said nothing about "fusion" and I ask you whether, given such a lamp, the sealing of which was defective, was it not the obvious thing to do to make that sealing perfect?

A. I don't know what would be obvious to other people. It was not obvious to me until I had reached that point, and when I did reach the point and got results I applied for a patent in which I claimed the conditions of an incandescing conductor in a chamber made wholly of glass, as claimed and shown in my Patent 223,898.

538 Re-x-Q. Please state whether an incandescing electric lamp, consisting of an illuminating chamber made wholly of glass, hermetically sealed, and out of which all carbon-consuming gas has been exhausted or driven, an electric circuit conductor passing through the glass wall of such chamber, and hermetically sealed therein, an illuminating conductor in said circuit and forming a part thereof, within such chamber, consisting of carbon make from a fibrous or textile material having the form of an arch or loop, is a practicable and operative thing?

A. If the carbon is a good one, and the chamber is

made entirely of glass, through which platinum wires, or wires having the same co-efficient of expansion as the glass, are sealed, and from which the air is exhausted, and if placed in an electric circuit, such lamp would be a practical lamp.

539 Re-x-Q. Your bambo carbon is a fibrous carbon, is it not?

A. Yes, sir.

540 Re-x-Q. It has an arch or loop shape, has it not?

A. Yes, sir.

(Signed) THOMAS A. EDISON.

Sworn to before me,

WILLIAM FARNHAM,

[L. S.] Special Examiner and Notary Public.

End of Edison's McKeesport Deposition.

BATCHELOR'S McKEESPORT DEPOSITION.

MARCH 7th, 1889.

CHARLES BATCHELOR, being duly sworn, testifies as follows:

> The same stipulation is entered into in regard to the testimony of the witness Charles Batchelor in the interference proceeding in the U. S. Patent Office, between Sawyer & Man and Thomas A. Edison, as appears of record in regard to the deposition of Thomas A. Edison; and the Examiner is requested to copy said deposition as part of this examination, and the deposition is accordingly entered as follows:

Batchelor's Interference Deposition.

Pursuant to adjournment, this testimony was continued Thursday, July 7th, 1881, at 65 Fifth avenue, New York, the same counsel being present.

Charles Batchelor, a witness produced in behalf of Mr. Edison, testified on oath as follows, in answer to questions proposed to him by George W. Dyer, counsel for Edison:

1 Q. Please state your name, age, residence and occupation.

A. Name, Charles Batchelor; age, 35; residence, Menlo Park, New Jersey; occupation, assistant to Mr. Edison.

2 Q. Please state how long you have been an assistant to Mr. Edison, and what your particular labors and duties have been in that capacity?

A. I have been assistant to Mr. Edison for nearly eleven years. My occupation has been entirely during the last eight or nine years the receiving of ideas and sketches, and afterwards carrying them out; making the necessary instruments myself, or with any help that I required. I have had general charge of all Mr. Edison's experiments during that time under himself.

3 Q. If you know of experiments of Mr. Edison's in 1876, in the carbonization of paper, please state about the same, somewhat in detail?

A. I remember some experiments in carbonization of paper in the summer or fall of 1876, in which paper carbon was made by him and myself for resistances, battery carbons, and other things that were to be sold by a company called the Novelty Company. I remember carbonizing strips of paper in pieces of gas tube; also sheets of paper in an old cast iron box which we had laying around his laboratory. I do not remember what kinds of paper were used, with the exception that I remember carbonizing a number of sheets of tissue paper. The other papers were a variety of papers

that were lying around the laboratory at the time. I also remember that we carbonized there paper called bristol board, besides a number of different kinds of wood.

4 Q. How extensive and long continued were these experiments in the carbonization of paper?

A. They were not very long-continued. I believe the experiments lasted not longer than a fortnight, as far as the Novelty Company was concerned. My impression is that I carbonized paper later than those experiments for our own use in the laboratory.

5 Q. Had you proceeded before the end of 1876 in the carbonization of paper so far that nothing more was needed in the way of information with regard to the proper carbonization, *per se*, of paper?

A. The experiments of 1876, of which I speak, answered their purpose as far as I am aware, the papers being properly carbonized. I believe we required to learn no more on carbonization for that purpose.

6 Q. During the time mentioned had you put such carbonized paper in electrical circuits?

A. Yes, sir; as some strips were intended for resistances, we had measured their resistance to see what variation there was in the carbonizing. I do not remember what resistance the carbon strips were, as we had no particular size for them.

7 Q. State, if you please, the next experiments you remember of as made under Mr. Edison's direction with carbonized paper?

A. The next experiment that I remember was the use of carbonized paper in telephones. I have found a paper which refreshes my memory on that point, which is dated July 20th, 1877, and about that time we used carbonized paper in telephones for contact points and diaphragms. The next experiment with carbonized paper that I can remember, is the cutting of strips of carbonized paper and putting them into the lamp on the table here, marked Edison's Exhibit First Incandescent Lamp. I believe the strips were cut from carbonized paper that had been carbonized by us in 1876, and I believe I put them in the lamp about August or September, 1877.

Question and answer objected to in so far as it relates to the lamp marked Edison's Exhibit First Incandescent Lamp, or in so far as it has any reference to electric lighting by incandescence with paper carbons, as going to prove that the invention was made and used previous to the time alleged in Mr. Edison's preliminary statement.

Paper referred to in the previous answer is put in evidence, and marked Edison's Exhibit No. 14.

Exhibit objected to as immaterial.

8 Q. When did Mr. Edison first begin to experiment in lighting by electricity, to the best of your knowledge, recollection or belief?

Objected to as calling for the mere belief of the witness, which is not evidence.

A. I know Mr. Edison had frequently made experiments in electric lighting previous to the time I put the paper carbon in the lamp marked Edison's Exhibit First Incandescent Lamp, but I cannot tell just exactly what those experiments were. He had been experimenting for about a day on electric lighting previous to his telling me to put this paper carbon in the globe of this exhibit at that time. I find by a record book of Mr. Kruesi's, which is now in evidence, and marked Edison's Exhibit No. 12, which I believe to be true, that he did some work on an electric lamp in January, 1877. This, no doubt, was under my direction, but I have no memoranda to recall to my mind what the experiment was.

9 Q. What is the earliest experiment, to your knowledge, which Mr. Edison made with paper carbon conductors in an incandescent electric lamp?

A. The earliest experiment that I remember is the

one in which I put the paper carbons in the lamp marked Edison's Exhibit First Incandescent Lamp.

Answer objected to as intended to prove that the invention was made before the date stated in the preliminary statement.

10 Q. Please give in detail the history of the construction or fitting up of Edison's Exhibit First Incandescent Lamp, so far as you know about it?

Objected to on the ground that it is intended to prove that the invention was made previous to the date stated in the preliminary statement.

A. The instrument marked Edison's Exhibit First Incandescent Lamp was originally a philosophical instrument, bought by Mr. Edison for his laboratory, and is called, I believe, a Gassiot tube or cascade, and was intended to show the discharge of electricity *in vacuo*. It had been in the laboratory, I believe, since 1875. It was made into an incandescent lamp by myself, at the request of Mr. Edison, in the summer or fall of 1877, he at that time wishing to try some experiments on incandescent carbon for lighting purposes. I put onto this instrument two binding posts, and also had made two clamps, which I put on to the ends of the rods inside the globe. At first Mr. Edison wanted a hard carbon piece put into the globe, but as I had great difficulty in making it small enough and getting it in, he suggested that I should cut the carbon from carbonized paper, of which we had a quantity in the laboratory at the time. I did so, and succeeded in giving him a few of the carbons in the lamp. I do not believe the lamp has been used for any other experiments since that time.

11 Q. Please explain how you got the paper carbons into the lamp and held them in position there.

Same objection as before.

A. It was a very difficult and tedious process to put the carbon in there, but I did it by unscrewing the ball from the top of the rod and also unscrewing the globe from the holder above the cock; also unscrewing the cock from the base; also unscrewing the packing cap. When these are all apart the top rod will drop out and the bottom rod can be left in the part having the cock. The carbon was now screwed to the clamp of the bottom rod whilst lying on the table. The other clamp was then screwed to the other end of the carbon, and all three together lifted and turned, so that the part having the cock would be topmost. The lamp was also turned upside down, and the rods and carbon carefully dropped through it. The top rod was then held until the packing and packing cap were put on, when the whole was screwed together again, and the ball replaced. The binding posts were put on the lamp to hold the connection wires from the battery.

12 Q. Please to state whether or not, after the carbon conductor was thus placed in position, the air was exhausted from the globe of the lamp, and if so, by what means?

Same objection as before.

A. After putting a carbon into the lamp the lamp was placed on the plate of an ordinary air-pump and the bulb exhausted as well as we could do it with that pump. The current of electricity was then applied to the carbon, and heated the same for some short time.

13 Q. Was the carbon brought up to a point of incandescence in the lamp?

Same objection as before.

A. Yes; the lamp did give light for a short time in each case.

14 Q. Please to state, if you remember, how numerous those experiments were?

Same objection.

A. I cannot remember just the exact number I put in, but believe there were at least four.

15 Q. Do you remember from what kind of paper those paper carbons were made?

Same objection.

A. I cannot be sure what they were made from, as I did not make them at the time for the experiment. I remember I took a carbon sheet that was thin compared with others we had, but what kind of paper it was I do not know.

16 Q. Do you remember what was the size of the strips of carbon paper with which you experimented in that lamp?

Same objection.

A. I had no particular size given me by Mr. Edison, and I do not think I measured them, but should judge I made them three-quarters of an inch long, and about a sixteenth wide. The thickness of the paper, I believe, was about seven or eight thousandths.

17 Q. Did you give this lamp to Mr. Edison to be filed by him as an exhibit with his testimony in this case?

Same objection.

A. No, sir; I may have been the means of calling his attention to the lamp, because I told him I was sure that he had tried incandescent carbon paper previous to the boron and silicon experiments.

18 Q. Who found the lamp previous to its being put in as an exhibit in this case?

Same objection.

A. I do not know who brought the lamp in here. The lamp has never been lost, for it has been lying around the laboratory, generally in full view, ever since the experiment of putting the carbon in it.

19 Q. Were there many other exhibits in the laboratory at the same time?

Objected to as immaterial.

A. There are and have been hundreds of such instruments in Edison's laboratory—relics of old experiments.

20 Q. How do you know that this Exhibit First Incandescent Lamp was made and experimented with, using paper carbon conductors, at the time you have testified?

Objected to as going to show that the invention was made previous to the date given in the preliminary statement.

A. I can only approximate the date of the putting in of the paper carbon from a paper in evidence marked Edison's Exhibit No. 13, which is dated October 5th, 1877, witnessed by me on or about that date, and in which silicon is used between two electrodes for incandescent lighting, and I know that the experiment on incandescent paper carbon, in the lamp marked Edison's Exhibit First Incandescent Lamp, was at least from one to three months before that.

21 Q. Is that recollection further strengthened by inspection of Edison's Exhibits Nos. 4 and 5?

Same objection.

A. It is, for I remember from them that we hoped at that time to get better and more stable results than we had previously got from paper.

22 Q. Referring to these Exhibits 4 and 5, state whether or not your signature upon the same is in your own handwriting, and, if so, when was it made?

A. I recognize my signatures on both of these papers, and know that they were put on there by me, on or about the dates marked on the exhibits.

23 Q. After the experiments with paper carbon conductors with Edison's Exhibit First Incandescent Lamp, what was the reason of making experiments with boron and silicon, and the other metals named in the Exhibits 4, 5 and 13?

Objected to as immaterial.

A. Mr. Edison hoped to get from them a more durable and unoxidizable substance than carbon for electric lighting.

24 Q. Referring again to Edison's Exhibit No. 13, please to explain what is shown and described in that exhibit?

Objected to as incompetent. That must appear by the exhibit itself.

A. Fig. 1, on Edison's Exhibit No. 13, shows three incandescent electric lamps, in which the light-giving substance is silicon, each placed around resistances in the line, so that only a portion of the current goes through the silicon, and the whole fed with electricity from a magneto machine.

The figure directly under this No. 1 shows three incandescent electric lamps, similar to the three in No. 1, but placed in multple arc, each one with its own resistance.

The bottom figure on this exhibit shows the same three lamps, I presume, although the word "silicon" is not there, and these three lamps are all placed in series. In all three cases the electricity is furnished by a magneto machine.

25 Q. Please make a similar explanation of Edison's Exhibit No. 4?

A. In Edison's Exhibit No. 4, figure 1 shows four of such lamps in multiple arc, and figure 2 shows three of such lamps in series, and an explanation is here made to show that other substances could be used besides silicon, as Mr. Edison has remarked on it that he has tried a number of other things, and suggests the better method of working either boron or silicon. He also suggests on this, mixtures of non-conductors and semi-conductors, in order to get a greater resistance when using low resistance material.

26 Q. After the experiments described by you with Edison's Exhibit First Incandescent Lamp, what were Mr. Edison's next experiments with carbonized paper for electric lamps?

A. The next experiments that I remember in carbonizing paper for electric lamps were a series of experiments he had me make in order to get a good and light carbon for a lamp which was to be worked on a partial incandescence. I made a great many carbons about August and September, 1878, a great many of which were made from paper. Some of these carbons, especially the smaller ones, were raised to incandescence in an exhausted bell jar of an air pump about that time. I believe I worked altogether, about that time, equal to about two months ordinary daily working.

> Answer objected to upon the ground that it related to experiments made and carbonized paper burnt for electric lighting previous to the date alleged by Mr. Edison in his preliminary statement.

27 Q. What were the size and the form of the paper carbon conductors used in these last-named experiments.

A. The thin ones were generally short—from two to three inches; the thick ones were sometimes as long as six inches: I believe I made as many as from fifty to seventy-five of the paper carbons, which ranged in diameter from three-sixteenths of an inch down to considerably below a thirty-second of an inch. It was difficult to get the small ones very long. The best method I found of making these carbons was to coat tissue paper, or very thin paper, with a mixture of tar and lampblack, and then roll them up on a flat plate very tightly.

28 Q. Have you any recollection of applying these paper carbons to a lamp such as shown in Mr. Edison's

Patent No. 224,329; if so, at about what time was that?

A. I do not remember a lamp similar to that shown in the patent referred to being made, except similar in principle. I made a lamp the same in principle as these, which I have found a portion of, in which one of these paper carbons was placed directly over six platinum points, and guided in its descent by an upright arm, having a projection on it, with a hole through which the carbon could slip. I believe this lamp was used with three points and six points. The lamp was both an incandescent and an arc lamp, a slight arc forming between the points and the carbon. I cannot exactly tell the date of this lamp. I believe it was previous to Mr. Upton's coming with us in the laboratory, which I think was in November, 1878. I produce a portion of this lamp, showing the base, and the six springs and holders screwed thereon, but the platina points have been taken out.

> Portion of the lamp placed in testimony and marked Edison's Exhibit No. 15.

> Answer and exhibit objected to as immaterial, and as referring to a lamp that is not an incandescent lamp, in the sense that that expression is used in the application for the patent in interference, but is an incandescent lamp, in which the illuminating carbon or electrode is being continually consumed.

29 Q. Was this lamp, Edison's Exhibit No. 15, put in electric circuit, and the paper carbon heated to incandescence?

A. Yes, sir.

30 Q. In this lamp, just referred to, was provision made to keep a constant electric continuity?

A. Yes, sir; the fact that the carbon conductor stood directly above the platinum or iridum points, and was free to fall by gravity, kept it always in contact with the points.

31 Q. Were other experiments made at about this

time by Mr. Edison, or under his direction, in connection with incandescent electric lights?

A. Yes, sir; at that time Mr. Edison was almost entirely occupied with incandescent electric lights. Mr. Edison about this time commenced the improvement of apparatus for getting a good vacuum. He was also experimenting at the time for the best dynamo-electric machine that could possibly be got. He was also endeavoring to get a lamp of high resistance from metals, such as platinum, nickle, iron and alloys of platinum-iridium. These experiments on the perfection of vacuum apparatus extended far into 1879.

32 Q. During that time, also, namely, the latter portion of 1878, were not experiments going on on incandescent paper carbon conductors, *in vacuo*?

A. I have mentioned that we made experiments in August or September, wherein we placed paper carbons, made by myself, in a vacuum, and raised them to incandescence by the electric current in the bell receiver of the pump. To the best of my recollection, after these experiments were tried, Mr. Edison's attention was turned more particularly to the getting of this lamp of high resistance, which he required, from metals instead of carbon. This he succeeded in doing to a great state of perfection; but in doing so he had been able to get an apparatus for making a vacuum which was far superior to anything we had had before; and it occurred to him that with such a vacuum, carbon, however small, should be able to stand without oxidizing, which it had always done before.

By consent this testimony was postponed to Friday, July 10, 1881, at 10 A. M., at same place.

Wm. H. Meadowcroft,
Notary Public,
New York County.

Pursuant to adjournment the taking of testimony was resumed July 8th, 1881, at 10 A. M., at the same place, same counsel being present.

33 Q. Please examine Exhibit Edison's Commercial Incandescent Electric Lamp, and state when lamps of that description were first made by Mr. Edison?

A. The lamp marked Edison's Commercial Incandescent Electric Lamp is one of a number of lamps made in October or November, 1879, and lamps of this description were first made about the middle of October, 1879.

34 Q. What kind of a lamp is this exhibit you have just testified about?

A. It is composed of a hermetically sealed globe, wholly of glass, through which two platinum wires project on the inside, and to which is clamped a carbon conductor made of paper carbonized. This globe is exhausted of air.

35 Q. When did Mr. Edison first produce an incandescent electric lamp with a carbonized paper conductor, in all respects complete and able to compete successfully with illuminating gas for light-giving purposes?

A. I believe about the middle of October, 1879, when he produced lamps similar to this lamp marked Edison's Commercial Incandescent Electric Lamp.

36 Q. At the date named, what progress had been made in generators, apparatus for producing vacuum, regulating apparatus, a system for lighting districts and other matters and things essential for a commercial light for general use in cities and towns?

A. At this time everything was ready, to the best of my belief, and was only waiting for the perfection of the lamp to make the whole system a success, as directly we got the lamp we, in the shortest possible time, exhibited just such a system to the public, that being previous to Christmas day, 1879.

37 Q. Please to give a summary in a connected way, mentioning dates, as far as possible, of the progress of the invention of incandescent conductors for electric

lights made of carbonized paper, from the beginning up to the completion of the commercial lamp?

Question objected to in so far as it may be intended to bring out anything appertaining to the electric lighting by incandescence with the experiments on carbonized paper previous to the date of the invention alleged in the preliminary statement of Mr. Edison in this interference.

A. The history of electric lighting by incandescence with paper carbon by Mr. Edison, as far as I know it, is as follows: In the summer of 1877 he used strips of paper, carbonized, as an incandescent conductor *in vacuo*, and the lamp in which they were used is now in evidence, and marked Exhibit Edison's First Incandescent Lamp. I should have said that I remember Edison, within a day or two previous to this lamp being made, using carbonized paper as an incandescent conductor between two electrodes of a battery, but in the open air. The next experiment or series of experiments, that I call to mind, are the ones which I have before spoken of as being made in August or September, 1878. At this time my whole time and attention began to be devoted to development of his system of incandescent electric lighting. These paper carbons were made by coating thin papers with lampblack and tar, and rolling up tightly into a rod, drying and carbonizing the same in a suitable furnace. Some of these paper carbons were put in between the two electrodes in an electric circuit, and raised to incandescence in a vacuum. At this time, carbons made of paper were not the only things that we tried as incandescent conductors in a vacuum. We made many experiments with hard carbons, wood carbons and some metals, such as platinum, nickel and iron. It had early been decided by Mr. Edison that the requisite material for his incandescent lamp should have a great resistance combined with the least possible surface, and I remember well that at this time and previous we used to expect that we should be able to get a substance for an incandescent conductor that would give us at least 500 ohms

resistance. The result of this latter series of experiments *in vacuo* had shown us that in order to get a high resistance lamp from carbon in any form, it would have to be cut in an exceedingly fine filament. The paper carbons which we tried were larger than we should have to use if we wanted a higher resistance. With the vacuum we then got, and which we considered at that time to be good, the carbons lasted at the most from ten to fifteen minutes in a state of incandescence. The experiments on platinum led us to hope that it might be easier to get a higher resistance from that metal than from carbon. From the date of the finishing of these experiments, which I believe, was towards the latter end of October, '78, Mr. Edison turned his attention to lamps in which the incandescing conductors were formed of metals and alloys of metals. During the last part of the year '78 and up to October, 1879, I made, at Mr. Edison's request, a very large number of lamps having platinum and platinum-iridium composing the incandescent conductor. A great many of these lamps had their conductors coated with insulating material, in order to be able to wind them up close and get them into as small a space as possible in order to offer the least radiating surface. Mr. Edison very frequently sat down at my table and worked for hours helping me on these experiments. Our conversation frequently was directed to getting the highest resistance in the least possible space. I remember once or twice during these conversations, early in 1879, he remarked how easy it would be to get this resistance if carbon was only stable. During the time that I was experimenting on these lamps he had been busy experimenting to perfect the different apparatus composing his electric lighting system as a whole. I had also worked on these matters, but as our lamp was an exceedingly difficult job, the majority of my time, both night and day, with the exception of a week or two in which I devoted some time to telephones, was spent on the lamp. He had succeeded in making a more perfect dynamo machine. In testing the lamps with platinum conductors he had been continually improving the apparatus for exhausting the globes. In October, 1879, when he had got a very perfect vacuum for his lamps, he suggested the use again of carbonized paper as a conductor, and accordingly he had me cut a fine filament of paper, which we carbonized and put in a globe. This filament, I believe, was cut straight from paper and bent round previous to putting in the carbonizing chamber. I do not remember what we did with this lamp afterwards; but within a day or so of that I cut a loop from paper similar in shape to the one now in Edison's Commercial Incandescent Electric Lamp. At the same time that these were being tried I also made lamps of loops of carbonized thread, carbonized flax, fine filaments of lampblack and tar rolled up and baked, and also, threads which had been treated with lampblack and tar previous to carbonization. All these things were used about the same time as incandescent conductors in electric lamps, the most satisfactory at the time being the carbonized paper loop which I had cut by hand. We immediately after this made a steel mold in which these loops could be cut quickly, and after a few experiments in the carbonization of them, in order to get their resistance as near as possible alike after carbonization, we made a number of these filaments and used them at an exhibition in Mr. Edison's house about the 2d or 3d of December, 1879. When the first lamp was made which had a fine filamentary carbonized paper conductor from which the light was given, which was about October 22d, 1879, then, I believe, we had a system of electric lighting that was complete and could compete with gas, and we proceeded as expeditiously as possible to exhibit it as such.

38 Q. Did you start a record of the life of the early lamps put in position at Menlo Park, and if so, is Edison's Exhibit No. 3 a transcript of the first fifteen pages of that record?

A. I started a record about January 2d, but at that time a number of the lamps had been burning on exhibition for some time, and I remember, on looking at Book 67, as I did not know the exact time at which

these lamps were put up, I allowed, as near as possible, for the time they had burnt. This is shown on page 1, where Lamp 142 is recorded by me on January 2d, 1880; and after marking its resistance I remark that it has burned at least 200 hours. I have compared the exhibit referred to with the book and see no variation.

39 Q. Please examine Note-Book No. 74. State whether you commenced said record and had it continued under your charge. State whether or not Edison's Exhibit No. 11 is a correct transcript from said note-book.

A. I have examined Book 74, and I find it is a continuation of the record of lamps commenced by me on January 2d, 1880, and was continued under my direction through Book 74. The Exhibit No. 11, as far as I can see, is a correct copy of the pages mentioned in the exhibit.

40 Q. Please state whether or not such records state the facts correctly.

A. They do. I was always very particular to have this attended to in a proper manner. It was the duty of Mr. Herrick to enter in these books their time, as they burnt, daily, and I believe that he did so. I was also very particular to have him mark down in the book the cause of their ceasing to burn; and if at any time he was not present when a lamp ceased to burn, it was generally made a note of by any one in the laboratory present and put on Mr. Herrick's desk, so that he could go, take out the lamp and examine it, noting its defects.

41 Q. Have you read the testimony of Sawyer & Man in this interference, and if so, have you carbonized paper in the various modes described by them?

A. I have read the testimony and have made some samples of carbonized blotting paper in the same manner that is described in their testimony.

42 Q. Please produce such specimens, describing what each one is.

A. I here produce specimens of ordinary blotting paper carbonized, which were carbonized in a square iron box filled with powdered charcoal. This carbonization was done in an ordinary fire.

Specimens referred to put in evidence and marked Edison's Exhibit No. 16.

I also produce a piece of carbonized blotting paper, the paper having been pressed before carbonization, as stated in answer to question 22 in Albon Man's testimony.

Said specimen is put in evidence and marked Edison's Exhibit No. 17.

I also produce a specimen—two sheets of ordinary blotting paper cemented and pressed together, as also stated in answer to question 22 of Albon Man's examination-in-chief.

Specimen put in evidence and marked Edison's Exhibit No. 18.

I also produce a specimen of several sheets of blotting paper cemented together without pressure and carbonized, which may be meant in answer 22 in Albon Man's examination-in-chief. All these specimens were carbonized in an iron box, packed in powdered charcoal and heated in an ordinary fire.

Specimen referred to put in evidence and marked Edison's Exhibit No. 19.

I also produce a number of sheets of blotting paper in which two or more are cemented together and carbonized, the cement being different in this case from the former ones.

Specimen put in evidence and marked Edison's Exhibit No. 20.

43 Q. Have you also carbonized paper in the manner described in your testimony as having been done

by Mr. Edison and under his direction, in the earlier experiments?

A. I have carbonized also some samples of tissue paper similar to the experiments on carbonization of paper that I have testified to as being in 1876, and here produce the same.

Carbons put in evidence and marked Edison's Exhibit No. 21.

I have also carbonized some samples of strips of Bristol board, which I also remember are like the ones carbonized in gas pipe tubes in the experiments of 1876.

Samples put in evidence and marked Edison's Exhibit No. 22.

44 Q. Where a paper carbon conductor has been re-carbonized and treated with the electrical current in a hydro-carbon bath, as testified to by Albon Man in answer to 67th cross-question, if such a conductor is heated to incandescence in an electric lamp, what part of the conductor produces light?

A. As the light from an incandescent conductor is all given off at its surface, and as the experiments which my experience has tried have shown that the treatment of an incandescent conductor in a hydro-carbon bath deposits carbon from the hydro-carbon on its surface and in the interstices, I believe that all the light would be radiated from the deposited carbon.

Counsel for Edison rests his examination of this witness here, and offers him for cross-examination.

Cross-examination by Amos Broadnax, Esq., Counsel for Sawyer & Man:

45 x-Q. The papers you say you carbonized in pieces of gas tube in the summer of 1876; please to state in

detail just how you carbonized the paper in the gas tubes?

A. A piece of tube was taken, such as is used for gas pipes. To the best of my recollection, from five to six inches long and having about three-quarters to an inch hole in it. A thread was cut on each end of this, and a screw cap fitted on each end. One end of this tube was completely closed by the cap being fitted tight on it. The other screwed on and off easily. The strips of paper that were carbonized in this tube were cut into lengths and put lengthwise in the tube, in which some powdered charcoal had been placed, and the tube was then packed full of powdered charcoal. In screwing the cap on to this we generally put a little moist clay on the thread to make it air-tight. There was more than one tube made for this purpose. I remember one smaller than this. I cannot give the exact size of the smaller one, but believe it was a piece of three-eighths pipe.

46 x-Q. How many pieces of your piping did you have fitted in that way for carbonizing paper?

A. I can only call to mind at present the two mentioned.

47 x-Q. What kinds of paper did you carbonize in these tubes?

A. Principally stiff papers, such as bristol-board. We also carbonized other kinds of papers, but I do not know that they were carbonized in these tubes.

48 x-Q. How much paper did you carbonize in these tubes?

A. I cannot say how much paper was carbonized in these tubes, as all the work that I did on this carbonizing was generally done at night. Mr. Edison and Mr. Adams, being there in the daytime, also carbonized, I presume, with the same tubes.

49 x-Q. How did you heat the tubes?

A. We put them into a common fire and heated them red hot, and allowed them to cool again before taking the carbons out.

50 x-Q. How long did you keep them red hot before taking them out of the fire?

A. I cannot say just how long; sometimes two or three hours. In some of my experiments I took them out of the fire red hot, and covered them up with ashes, so that they would take a long time to cool off.

51 x-Q. These paper carbons that were made in the gas tubes, how long were they, how wide, and how thick after being carboniezd?

A. I do not remember that we cut them any particular size. The ones that I carbonized were generally about three and a half to four inches long, about three-eighths of an inch wide, and the thickness of ordinary bristol-board. I do not believe that I ever measured this bristol-board for thickness, but believe it was about the thickness of an ordinary visiting card. This was the size, as near as I can recollect, when they were put in.

52 x-Q. How many pieces of paper did you put in at one time?

A. I put no specified number each time, but I believe I sometimes had as many as six in the large one.

53 x-Q. What were these paper carbons used for?

A. As far as I was concerned, they were specimens of carbonizing. Mr. Edison and Adams I believe tested them for resistance and used them as such. I do not remember making any instrument myself in which these were used as resistances.

54 x-Q. Did you see Mr. Edison use them as resistances in any instrument, and if so, what instrument?

A. I had seen Mr. Edison testing their resistance with a Bradley galvanometer. Previous to this I had made for Mr. Edison resistances of powdered carbon, also resistances of plumbago on wood. At the time of these carbonizing experiments the majority of my time was taken up in New York, and the experimenting that I did on this was at night.

55 x-Q. I asked you if you had seen Mr. Edison use any of the carbons carbonized in the gas tube as resistances in any instrument, and if so, what instrument?

A. I simply saw him measure one or two of these carbons, and in those cases they were resistances in an instrument when being measured.

56 x-Q. Well, what instrument were they used in?

A. The Bradley galvanometer.

57 x-Q. Did you see them used in any other machine; if so, what?

A. I do not remember seeing him use them as special resistances for other experiments, but know that they were carbonized with a view towards getting carbons for resistances, as I believe that was one of the things we proposed to give to the Novelty Company.

58 x-Q. Was any practical use made of these carbons, and if so, what; I am referring to the carbons made in the gas tubes all the time?

A. I do not remember that there was any practical use made of these special carbons, as the experiments were never carried far enough to make an instrument from them suitable for the Novelty Company to sell.

59 x-Q. Did you undertake these experiments in carbonizing paper in the gas tubes upon the request of Mr. Edison?

A. I did, although I was not working at them all my time. I believe Mr. Adams carbonized and carried on the experiments more than I did.

60 x-Q. But you initiated the experiments, as I understand you?

A. No, sir. Mr. Edison commenced the experiments and we simply helped to carry them out. If I remember right, the stoppage of the Novelty Company for want of funds stopped these experiments for them.

61 x-Q. When you undertook these experiments or commenced to assist Mr. Edison in making them, did he explain to you his object in carbonizing paper?

A. I believe I remember that in conversation with myself and Adams on the things that should be given to the Novelty Company, when he mentioned the different articles to be made from carbon, he then said that we could get any resistance we wanted from paper carbonized. We had been using previous to that resistances for cable work which had been made of carbon, but which did not keep their resistances well, as they were made from powdered carbon packed in tubes. A cheap and high resistance carbon was a desideratum

for cable experiments, if it could be made constant. This, I believe, was Mr. Edison's idea when he propesed to have the Novelty Company sell resistances which were made of carbonized paper.

62 x-Q. These paper carbons which you say you made with a gas tube, were any of them considered commercially salable for the purposes you have mentioned?

A. As the experiments were never carried to such an extent that we had a standard instrument made of these carbonized paper strips, I do not consider that they were a commercially salable article.

63 x-Q. Can you produce any of the carbonized paper made by you in the gas tubes in the experiments about which you have testified?

A. I canrot; to my knowledge, for a year or so after these carbonizing experiments, I believe, there were some of these strips carbonized in gas tubes lying around the laboratory, but I cannot say whether there are any there now.

64 x-Q. Have you, upon your examination-in-chief, produced any specimens of carbonized paper made in a gas tube similar to those about which you have testified?

A. I have produced and put in evidence strips of carbon paper which have been carbonized in substantially the same manner as those described as being carbonized in a gas tube. These strips, however, were carbonized in a small iron box with the cover luted on, and not screwed on as in the tube experiments. This was heated in a boiler fire. This method is substantially the same as the gas tube experiments.

65 x-Q. Which one of the exhibits contains the carbons referred to in your last answer?

A. That marked Edison's Exhibit No. 22.

66 x-Q. What kind of papers are these carbons made of—Exhibit 22?

A. These paper carbons are made from what is known as bristol-board.

67 x-Q. And they were made in an iron box, and not in a section of gas tube, as I understand you?

A. Yes, as I had not a section of the gas tube. A section of the gas tube would probably have made me a more perfect carbon, as the screwing of the cover on is less likely to allow air into the chamber than the mere luting of it up.

69 x-Q. How big was the box in which you made these carbons, Exhibit 22?

A. The box was somewhere about five inches long, about two inches wide, but about four inches deep. The box was filled to within an inch of the top with powdered charcoal previous to my putting these card-board strips in. I used this box simply because I had it. If I had had to make a box, I should have preferred the gas tube, in order to make the experiment the same as in 1876.

69 x-Q. How many paper strips did you put into the box when you made this Exhibit 22?

A. I did not count the number of paper carbons in the exhibit, but I think they are all there that I put in in the form of paper.

70 x-Q. Then, these were all made at once, as I understand you?

A. Yes.

71 x-Q. After you had the strips of paper put in the box on the pulverized carbon, did you cover the strips with pulverized carbon also?

A. Yes, sir; pressing down the carbon, so as to get in as much as possible and as tight as possible.

72 x-Q. Did the lid of the box screw down on it, or how was it fastened on?

A. The box lid had a projection on its under surface that extended into the box about an eighth of an inch. We took moistened clay and plastered all around the projection, and then pressed it to its place carefully. The moistened clay filled the crevice all around the box. It was not screwed or otherwise fastened down.

73 x-Q. Was the lid of the box held simply by the clay?

A. The lid of the box does not depend on the clay to be held, as we kept it in one position, and it stayed there by its own weight.

74 x-Q. Then, as I understand you, the only pressure there was upon the powdered charcoal and the strips of paper in the box was that due to the weight of the lid of the box?

A. Yes.

75 x-Q. In making these carbons, Exhibit 22, was it your intention to show just the quality of paper carbon you made in the gas tubes in the summer of 1876?

A. My intention was to show paper carbons made in a similar manner and with the same material as those we made in the summer of 1876 in the gas tube.

76 x-Q. Why didn't you make them in exactly the same way that you did in 1876?

A. I should have done so if I had had time.

77 x-Q. When did you make these, Exhibit 22?

A. Early this morning; between half-past twelve and three o'clock.

78 x-Q. For the purpose of this examination?

A. Yes, sir.

79 x-Q. How do these carbons, Exhibit 22, compare in quality with those you made in the gas tube in the summer of 1876?

A. I can only tell from their appearance. As near as I can recollect, they are very similar in appearance.

80 x-Q. Were those you made in the gas tube as entirely unbroken as these are?

A. As far I can remember, they were as unbroken as these.

81 x-Q. Now, that we have got through with the carbons made in the gas tube and the carbons of Exhibit 22, I call your attention to the sheets of paper carbon you made in an old cast-iron box that was lying around the laboratory in 1876. Please to give the several dimensions of that box, as near as you can recollect them?

A. As near as I can recollect, the size of the box named was about five inches in diameter and about two inches deep; the box was circular; there was no regular cover to this box, but we used a piece of sheet-iron.

82 x-Q. How large were the sheets of paper that you carbonized in that box, and what kind of paper was it?

A. I remember only two kinds of paper that I ever carbonized in that box myself, and they were tissue paper and cardboard. I believe many other kinds were carbonized, but do not remember doing it myself. The size of the sheets, I should judge, was not more than about three inches by two, or thereabouts.

83 x-Q. What you believe is not evidence. Please to confine your answer to what you know and what you remember, and state, if you please, how you charged the box, and how much paper you put in in each charge, and how often you charged it?

A. It is impossible for me to remember at this late date, without anything to refresh my memory, exactly how many times I charged the box, or how many papers I put in each box, or in what way I charged each box. I can only say that the experiments I tried for Mr. Edison with this particular box were those in which he required me to get a flat paper carbon after carbonization. The box sometimes had the bottom covered with powdered charcoal, and then a paper sheet; afterward another layer of powdered charcoal, and then another paper sheet. This was continued for a number of sheets in some experiments. In other experiments fewer sheets were put in, and a weight of iron placed on the top to keep them straight.

I tried a number of devices, and finally succeeded in bringing out flat carbons by putting a heavy weight on top of the successive layers of cardboard and powdered charcoal.

84 x-Q. Having the box thus charged, and forced down by a weight, in what kind of a furnace did you heat it?

A. Sometimes it was heated in a stove; at other times in a small boiler furnace.

85 x-Q. Were the carbons thus made straight flat sheets, or were they more or less crooked?

A. The carbons in some of the experiments were exceedingly crooked. The problem was, with me, how to make them come out straight. I succeeded in this by putting heavy weights on them and leaving the weights on until they were cold.

86 x-Q. And then were the carbon sheets whole or were they more or less fractured?

A. There was no difficulty, that I remember, with the breaking of the carbons. Sometimes some would be broken in taking them out.

87 x-Q. What proportion of all the carbons which you made in this box were straight and perfect?

A. Only a small proportion of the carbons that I made myself in this box were straight and unbroken, but when I left off experimenting with that box I could bring out almost all the papers I put in as straight and perfect carbons.

88 x-Q. And was this perfection of the carbons, referred to by you in your last answer, due, in your opinion, to a sufficient weight upon them and to uniform heating and cooling of them?

A. When I spoke of the perfection of the carbon in that last answer I meant its perfection of form and shape, unbroken. There was no effort at uniformity on my part at that time to get uniform heating other than from an ordinary fire, but I frequently endeavored to get uniformity of cooling by covering it over with the ashes of the grate.

89 x-Q. These sheets of paper carbon that you at last succeeded in getting straight and whole, of what kind of paper were they made?

A. I believe, principally, of ordinary cardboard.

90 x-Q. Cardboard is of various thickness. State about how thick the cardboard was that you used to make these carbons, as near as you can recollect?

A. About the thickness of an ordinary visiting card.

91 x-Q. What use did Mr. Edison make of these sheets of carbon you made in this box in 1876?

A. I do not remember any use that they were put to; as well as I can remember, the flatness of the carbons was requisite for making carbons for batteries, and in order to make the generality of battery carbons we should have to have larger molds and larger sheets;

the experiments, I remember, resulted merely in getting flat sheets of carbon from paper.

92 x-Q. Can you produce any specimens of the carbons made in this box in 1876?

A. I cannot; I have looked in Edison's laboratory for some specimens of these paper carbons, but, although I can find plenty of carbonized paper, I could not bring any here that I could swear was carbonized by us in 1876.

93 x-Q. Have you produced here to-day any specimens of carbonized paper intended to show the quality of the carbonized paper you made in that box in 187 , other than these contained in Exhibit 22?

A. Yes, sir; I have put in evidence here some carbonized tissue sheets which are marked Edison's Exhibit 21, which are substantially similar to some tissue sheets that I carbonized in the iron box in 1876.

By consent the taking of further testimony was postponed to Saturday, July 9th, 1881, at 10 o'clock A. M.

Wm. H. Meadowcroft,
Notary Public,
New York County.

Pursuant to adjournment this examination was continued on Saturday, July 9th, 1881, at 10 o'clock A. M. the same counsel being present.

94 x-Q. Are these carbons of Exhibit 21 carbonized in the same box that the carbons of Exhibit 22 were carbonized in, and in the same way and at the same time?

A. They were carbonized in the same box but not at the same time; they were carbonized in the same manner, between eleven o'clock the night of July 7th and three o'clock the morning of July 8th, 1881.

95 x-Q. Are these carbons of Exhibit 21 suitable carbons out of which to make illuminating conductors for Mr. Edison's incandescent electric lamp.

A. No, sir.

96 x-Q. The same question as to the carbons of Exhibit 22?

A. I cannot say, as I have not tried them.

97 x-Q. What is your opinion about it?

A. My opinion is that the carbons in Exhibit 22, if used as incandescent conductors in an electric lamp, would answer that purpose; as the carbonizing we do now for Edison's electric lamps is no different in principle from the way in which we carbonized the strips in 1876.

98 x-Q. What time in the year 1876 did you commence these experiments of carbonizing paper, about which you have been testifying?

A. I cannot give the exact date, as I have no memoranda to refresh my memory; the particular year, 1876, I remember, as during that year I spent a great part of my time in New York selling and perfecting the manufacture of Edison's electric pen; it was about the time of the organization of the Novelty Company.

99 x-Q. At the time these experiments were made what reference did they have to electric lighting?

A. I know of none.

100 x-Q. Referring now to the exhibit marked Edison's First Incandescent Lamp, please to state whether the lamp is now in the same condition it was when you made the experiment in it about which you have testified?

A. As far as I can see it is in the same condition as when I put the paper carbons in for Mr. Edison.

101 x-Q. These experiments, as I understand you, with this lamp, were undertaken by you at the request of Mr. Edison in the latter part of the summer or the early part of the fall of 1877?

A. Yes, sir.

102 x-Q. When Mr. Edison requested you to undertake these experiments, what did he say to you?

A. As near as I can recollect his words were: "Batch, put me a piece of carbon in this," and I believe he brought the globe to me at the time.

103 x-Q. Is that all he said to you upon the subject

of the experiment at the time—did he say nothing about the object of the experiment?

A. At that particular time that was all that I remember; but when I had finished the instrument, and was making a thin carbon to put in, and he saw the difficulty I had to get it thin enough, he suggested to me to cut the carbon from some of the carbonized paper that was lying around. I do not remember that he said anything to me at that time about the object of the experiment. It was quite apparent to me what he wanted to do.

104 x-Q. When did he first say anything to you about the object of the experiment?

A. I cannot call to mind the first time he spoke of the object of this experiment.

105 x-Q. State the first time you recollect of his speaking to you about it, and state what he said?

A. I cannot give any particular time when he spoke of the object of this experiment. At the time this experiment was made my time was not wholly devoted to experimenting on electric lighting, and the experiment only occupied my mind for a short time, as I had to make it for him. It was a frequent occurrence for me to break off experimenting on one thing to make an instrument to illustrate some idea of Mr. Edison's.

106 x-Q. After you succeeded in getting the carbon in this lamp, to what degree of luminousity did you succeed in raising it?

A. I cannot tell the exact degree. I remember Mr. Edison and Adams made the experiment with it, and I remember that they all came to incandescence before oxidizing or bursting.

107 x-Q. How long were they maintained in a state of incandescence before they were destroyed?

A. I cannot say, but they lasted a very short time.

108 x-Q. Well, about how long?

A. None of them I believe lasted more than from ten to fifteen minutes.

109 x-Q. Did you see these experiments yourself?

A. I was present and saw them, but did not direct the experiments, Mr. Edison doing that himself, as my

mind was not on that. I was simply curious to see the result and did see it.

110 x-Q. Then you can tell me whether the carbon was raised to a red heat, to a yellowish heat, or to a white heat. Give me as near as you can the degree of luminosity or color of the carbon that was obtained in those experiments.

A. In those experiments the carbons were raised through the red and yellow to a white heat, and generally before bursting gave a very brilliant light. The degree of luminosity I cannot say.

111 x-Q. How many carbons were put in this experimental lamp?

A. I cannot say the exact number, but am sure there were more than two. I could not swear to there being more than six or seven.

112 x-Q. All that was put in, as I understand you, you put in?

A. Yes, sir; as far as I know.

113 x-Q. How large were the carbons. Give their several dimensions, as near as you can recollect?

A. I cannot give their dimensions exactly, but I remember the first one was the widest. Their lengths, as near as I can remember, were about alike, and their thickness. I do not believe that any of these carbons were more than an inch long or less than three quarters of an inch. Their width was not more than one-quarter of an inch nor less than one-thirty second of an inch, and their thickness, as near as I can judge, without anything to refresh my memory, would be in the neighborhood of from seven to ten-thousandths of an inch. As I did not carbonize these especially for the purpose, but cut them from already carbonized sheets, this measurement is as near as I can get.

114 x-Q. What degree of vacuum did you obtain in the glass chamber or globe of this lamp in which you illuminated a carbon?

A. That I cannot tell; but I know that the vacuum pump, on the platen of which this was exhausted, will not, under any circumstances, give a state of exhaustion which I should call a good vacuum now. At that time

I believe they pumped until they could see no diminution in the column of mercury, and then stopped.

115 x-Q. When Mr. Edison saw the carbons illuminated in this experimental lamp, and saw them go out or destroyed by the current, as you have stated, what did he say?

A. I cannot remember what he said, with the exception that he wanted another one in, and I proceeded immediately to put one in. My attention was taken with this, and I cannot remember what he said at the time, or whether he said anything further than expressing a wish to have another one put in.

116 x-Q. After he saw the last one burn and go out what did he say?

A. I cannot remember at this time that he said anything in particular.

117 x-Q. Didn't make any remarks about the experiments at all?

A. I cannot remember that he made any at all at that time.

118 x-Q. Why did he undertake the experiments?

A. Because his mind was running on experimenting with electric light as one of the after things of the telephone, for many months during our experimenting with that telephone, and before my time was devoted entirely to the light.

119 x-Q. What did he undertake to prove by these particular experiments?

A. He did not undertake to prove anything to me about them. I knew from these experiments that he had me try what his object was to do; they needed no explanation.

120 x-Q. How did you know what his object was?

A. I knew that he thought some on electric lighting. I saw him for a day or two working at a table near my table experimenting with a battery and pieces of material in between the electrodes, and I knew, without being told, that he was experimenting in electric lighting. Paper carbons were part of the same series of experiments, and he gave them to me because I was more used to doing work of that kind than he was, or, at

least, I suppose so. My principal time, and almost all my energy at that time, was on telephones.

121 x-Q. Then, as I understand you, you ascertained what Mr. Edison's object was in making the experiments with this exhibit, Edison's First Incandescent Lamp, by what you saw him do, and not by what you heard him say?

A. Yes, sir; by what I saw him do and what he had me do.

122 x-Q. Now what did you see him do, and what did he have you do, that showed you the object of his experiments?

A. As I said before, I saw him experimenting on electric lighting. He had me put paper carbons in the lamp marked Edison's First Incandescent Lamp, and I saw from that, that in this case, he wanted to make an incandescent electric lamp, in which the incandescent material was carbonized paper *in vacuo*.

123 x-Q. And that, as I understand you, is all that you saw him do and all that you have done, that led you to that conclusion?

A. Yes, sir; that is all that was needed to lead me to that conclusion. I afterwards saw him raise these carbons to incandescence in a vacuum, proving to me that such was the case.

124 x-Q. When did you see him raise the carbons to incandescence in the vacuum afterwards; was it at the time of these experiments or afterward?

A. Immediately on my giving him the lamp with each paper carbon fixed in place.

125 x-Q. Then, from the facts and circumstances which you have related, you inferred, as I understand you, that Mr. Edison's object was to make an incandescent lamp, in which the illuminating conductor should be of carbonized paper?

A. Yes, sir.

126 x-Q. How well did Mr. Edison accomplish this object at that time?

A. The lamp was complete, and gave light for a short time. It was not a commercial success. As a lamp for a few minutes, it was a success.

127 x-Q. If that was Mr. Edison's object in making those experiments, why did he tell you first to put hard carbon in the lamp, and then when he saw how much trouble it was to get in the hard carbon, direct you to put in strips of paper carbon?

A. I do not know why he told me to put in the paper carbon, except that I know he did so.

128 x-Q. Now, in putting this carbon in this lamp, I understand you to say that you screwed the glass globe off of the pedestal, in which the cock is placed below the globe?

A. Yes, sir.

129 x-Q. That you screwed the ball off the top of the stem?

A. Yes, sir.

130 x-Q. And the gland off the stuffing-box?

A. Yes, sir.

131 x-Q. And took the packing out of the stuffing box?

A. Yes.

132 x-Q. And made the clamps on the end of the rod that forms the conductor in the chamber of the lamp?

A. Yes, sir.

133 x-Q. That you took the piece of carbon and fastened it in the clamps?

A. Yes.

134 x-Q. That you then screwed the lower end of the conductor in the top of the pedestal in which the cock is placed under the globe of the lamp?

A. I either screwed it in there or fastened it in tightly.

135 x-Q. You then passed the whole conductor up through the bottom of the globe, the upper end of the conductor passing up through the stuffing box, the globe being turned right upside down?

A. Yes.

136 x-Q. You then, while the globe of the lamp was in an inverted position, screwed the pedestal in which the cock is placed in the bottom of the globe?

A. Yes.

137 x-Q. Then put the packing in and screwed in the gland?

A. Yes, sir.

138 x-Q. Now, after you had got the carbon in the lamp, and the lamp together in that way, how did you exhaust the air out of the globe?

A. This was done by an ordinary air pump. The base of this lamp, being true, was placed right over the exhausting hole of the platen, and the air drawn out of the lamp. This, I believe was done by Adams.

139 x-Q. How could the air be drawn out of the globe of the lamp unless there was an open passage between the air pump and the globe of the lamp?

A. You will find that there is such a passage in the inside of the lamp, I believe, where the screw is driven in.

140 x-Q. On an examination of the lamp I do not find any such passage. Please to point it out?

A. You will find there are two small grooves, one on each side of the rod of brass, through which, if the grease was cleaned out of the lamp, you would be able to suck air.

141 x-Q. When were these experiments with the Exhibit Edison's First Incandescent Lamp concluded?

A. They only lasted a few days altogether with this particular lamp, in the end of the summer or beginning of the fall of 1877.

142 x-Q. Did you experiment with any other lamps at that time?

A. I do not recall to mind making any more lamps for Mr. Edison about that time.

143 x-Q. I read to you your answer in examination-in-chief to question 26?

Counsel reads question and answer.

Were all the carbons that were then illuminated—I mean at the time referred to in your answer, which I have just read—illuminated in the bell receiver of the air pump, or did you then have at that time, in the fall of 1878, a lamp made having a glass chamber from which the air was exhausted, and into which you put these carbons to illuminate them?

A. As far as I remember they were all illuminated in one of the bell jars belonging to the pump.

144 x-Q. What was the shape of these carbons?

A. They were as near as we could get them to short, straight sticks.

145 x-Q. Did you experiment with other carbons besides paper carbons at the same time?

A. Yes, sir; during the same series of experiments.

146 x-Q. How long did that series of experiments last, and when was it concluded, as near as you can recollect?

A. I cannot say just what time I gave over experimenting myself on these; probably about the end of September, 1878.

147 x-Q. After you concluded your experiments in the fall of 1878 with the carbonized paper in the bell jar of the air pump, when did you next use carbonized paper for illuminating in an electric lamp?

A. Shortly after the experiments referred to. Mr. Edison used some of these carbons in the electric lamp Exhibit No. 15.

148 x-Q. Was that a sealed lamp in which the carbons burnt *in vacuo* or in an innert gas?

A. No, sir; the carbons burnt in the atmosphere.

149 x-Q. When did you next use carbonized paper for illuminating in a sealed electric lamp, out of which the air had been exhausted, after you had completed your experiments in the fall of 1878—I mean the experiments in the bell jar of the air pump?

A. About the middle of October, 187., within a day or so of the time that the first of the style of lamp of which Edison's Exhibit Commercial Incandescent Lamp is one, was made.

150 x-Q. In that case, as I understand you, the carbon was substantially of the form of that shown in the Exhibit Edison's Commercial Incandescent Electric Lamp, and the lamp was made for the purpose of burning an incandescent conductor of carbonized paper, or something substantially the same as carbonized paper.

A. It was substantially the same with this exception, that I remember, the first loop that was cut was cut straight and bent round when put into the carbonizing chamber. The lamp was made for the purpose of a lamp; with the exception that I have mentioned, the lamp was similar to this exhibit.

151 x-Q. When did you first cut the paper of the form substantially shown in the Exhibit Edison's Commercial Incandescent Lamp before carbonizing?

A. I believe I cut them during October, 1879. My impression is, between the 20th and 25th. I think I could find the record somewhere amongst our books to that effect.

152 x-Q. Then, as I understand you, the first sealed incandescent electric lamp or lamps that Mr. Edison made, or caused to be made, as a lamp, in which he used carbonized paper for the illuminating conductor was made in October, 1879?

A. With the exception of the Exhibit Edison's First Incandescent Lamp, and the experiments I have mentioned in the bell jar of an air pump, the lamp made in October, 1879, was the first lamp which answers the conditions of your question.

153 x-Q. Referring now to Exhibit No. 16, please to describe exactly how you carbonized that paper, and what kind of blotting paper you used?

A. The Exhibit 16 is ordinary blotting paper similar to that which I now put in the box with Exhibit 16, and mark in ink with my initials. These sheets were carbonized in the same box that I have spoken of as being one in which Exhibits 21 and 22 were made. The paper was put in the box, tightly packed with powdered charcoal between each sheet. They were made to show what kind of carbon ordinary blotting paper makes when carbonized substantially the same as is spoken of in Mr. Man's testimony.

154 x-Q. How did you fasten the lid down on the box in this case; the same as in the other case?

A. I did not fasten the lid down by wire, as spoken of in one of Mr. Man's statements, as the lid of my box has a projection going inside the box.

155 x-Q. Was there any pressure upon the paper during the operation of carbonization?

A. None except the weight of the lid.

156 x-Q. Was the full weight of the lid upon the paper?

A. No, sir; the lid rested on the tightly packed powdered carbon. The papers were some distance from the surface.

157 x-Q. Did you saturate the paper with any carbonaceous material, put it in a hydraulic press and press it hard before carbonizing?

A. I did not saturate this exhibit with anything, nor did I press it. I, however, pressed a piece of the blotting paper under a powerful screw press and carbonized that. I did not, however, saturate this with anything. I have produced this and it is here marked Edison's Exhibit No. 17. I made these to show the kind of carbon that blotting paper made, whether pressed or in its ordinary state.

158 x-Q. What experience, if any, have you had in treating paper carbons electrically in the presence of hydro-carbon gas?

Question objected to as being new matter not brought out upon examination-in-chief.

A. I have had considerable experience in treating carbonized paper used as an incandescent conductor in hydro-carbon vapor in connection with the paper carbon loops of Edison's electric lamp?

159 x-Q. What effect does such treatment have upon the paper carbon burner?

A. It deposits carbon from the hydro-carbon on the surface of the incandescent conductor.

160 x-Q. Doesn't it fill up the interstices and consolidate the carbon—making it finer and more compact?

A. It probably does fill up the little interstices on the surface, but I do not think it makes the paper carbon any more compact. It adds to that by coating on the surface. I have frequently broken these conductors that have been treated in the vapor of the hydro-carbon, and, under a powerful microscope, have found that the fracture of the paper carbon showed no greater density, and the deposited carbon sticking to it in the shape of small needles stuck endwise on it.

161 x-Q. In the presence of what kind of hydro-carbon gas did you treat the carbon; how high did you raise its temperature or luminosity?

A. In our experiments we have generally used the vapor gasoline, benzine and such vapors. The carbons were raised to different temperatures, but were always raised to brilliant incandescence when we were depositing this carbon.

162 x-Q. Under what pressure of the gas did you treat the carbon?

A. I do not know what pressure we had. The chambers that I had made for our experiments in the experiments I speak of always had a small outlet, so that the vapor could escape, and we made it while the experiment was going on. We did not create an artificial pressure for the purpose of treating carbon under pressure. If there was any pressure at all it was an incidental pressure, while we were making the gas.

163 x-Q. How large were the carbons you treated?

A. Some of the carbons were the same as the one in Exhibit Edison's Commercial Incandescent Electric lamp. The other carbons were about the same size, but made from different fibres.

Re-direct Examination by George W. Dyer, Counsel for Edison:

164 Q. Do you wish to explain your testimony in regard to first putting carbons into the lamp, Exhibit Edison's First Incandescent Lamp—if so, please make your explanation?

A. Yes; in my direct testimony I testified that Edison wanted a hard carbon put in that lamp, so that it reads as if he requested that it should be specially hard carbon. I could not swear that he especially wanted a hard carbon, but that he told me, as I have afterwards stated, to put a carbon in the lamp, and I proceeded at that time to put a hard carbon in, supposing that was what he wanted.

165 Q. Referring to your answer in cross-examination about the Exhibit First Incandescent Lamp, state, if you remember, how long before the experiments with the lamp was the lamp made, as a lamp ?

> Question objected to, and all testimony appertaining to the alleged lamp—Edison's First Incandescent Lamp—as tending to prove that the invention was made before the date alleged in the preliminary statement; because the question assumes that the so-called lamp was ever made for a lamp.

A. The lamp was used as a lamp within a day of its being made as a lamp.

166 Q. At the time of these experiments with this exhibit, do you wish to be understood that the only conversation Mr. Edison had with you in regard to electric lighting by incandescence was the direction to put a carbon in that lamp?

A. Previous to that time and after that time, Mr. Edison had frequently spoken of electric lighting for domestic purposes as a big field for experiment when we had the telephone and some other things off our hands. He frequently tried experiments himself whilst we were working on these other things. He knew that I was conversant with the experiments and the end they tended towards, and therefore his order to me, to put the carbon in, that needed no further explanation from him as to what he proposed to do.

CHAS. BATCHELOR.

End of Batchelor's Interference Deposition.

Continuation of Batchelor's McKeesport Deposition.

MARCH 7, 1889.

THE WITNESS, CHARLES BATCHELOR, BEING FURTHER INTERROGATED, AS A PORTION OF HIS DIRECT EXAMINATION BY WALTER K. GRIFFIN, ESQ., COUNSEL FOR THE DEFENDANT, TESTIFIES AS FOLLOWS :

167 Q. What is your name, age, residence and occupation ?

A. Charles Batchelor ; 43 years of age ; I reside in New York City ; I am assistant to Thomas A. Edison ; as such my duties have been for the last nineteen years the carrying out in a practical manner the ideas of Mr. Edison generally in his laboratory with a large force of men, at other times building and designing especial machinery for the various businesses that his discoveries and inventions have created. At present I am commencing the manufacture of his phonographs part of my time, the rest of my time superintending a large number of his experiments in the laboratory.

168 Q. I hand you a book and ask you to state what the same is ? (Book handed witness).

A. The book referred to is Vol. 52 of a series of books in which records of experiments were kept at the time we were in the Menlo Park laboratory, and refers principally to experiments that I carried on for Mr. Edison in the latter part of 1879. It is especially a book that was alway kept on my personal work table. Whilst I had general charge of the place I still did a very large amount of personal experimenting. I wrote in almost all the books that were around the shop, but this one in particular is almost entirely in my own hand-writing.

169 Q. Did you have the book in your possession or know of its whereabouts at the time of your deposition in the interference ?

A. I believe not. The book was mislaid at the time of this interference suit and I was rather surprised to see it brought here again. The reason we always gave for the losing of some of our books was the fact that they contained records of our experiments very largely on telephones, and many of such books were put or used in interference cases. I do not think that there are many telephone experiments in that book, but we could not find it at the time.

170 Q. With the aid of the book please state your recollection of the experiments in electric lighting made by Mr. Edison or by yourself under his direction so far as the same are referred to in the book, having special reference to such experiments as involved the use of carbons for the purposes of illumination ?

A. The first part of the book relates particularly to that part of a line of experiments where Mr. Edison required a very high resistance conductor to be used in an incandescent lamp and in which the incandescent part should occupy a small space. It was particularly necessary for these experiments that the incandescent conductor should have a high resistance, and those experiments relate to metal conductors. The rest or two-thirds of the book about consists in experiments for incandescent conductors to be used in lamps made from carbons carbonized from very many different substances and formed into many different shapes. They refer to lamps made from carbons carbonized from tarry matters, threads of different kinds, papers of many kinds and many other materials. My recollection of these is that there were many of them that were very excellent lamps, and I find some of them of which there were large numbers used at the same time. Those lamps which involved the use of carbon were generally very good lamps; my part of the work there was generally to make the incandescent conductor, place it in its position and give directions to the glass blower to put it in its place, after which it was generally put on the pump by one of our assistants, after which I got a statement of its value as a lamp. The latter part of the book consists mainly of lamps with incandescent conductors of carbonized paper and of these lamps there were a great many made, as many as seven or eight hundred of them being used in Menlo Park at

one time. In regard to the carbon experiments I find that we made incandescent conductors, October 7th, 1879, carbon spirals. These were made from paper tarred, rubbed with tar and lamp black and rolled into the shape of a thread. They were then wound in a spiral form on a special device for that purpose, carbonized, and afterwards put into lamps. These were also made of powdered electric light carbon, which was made into a pasty mass, then rolled up in the form of a thread, carbonized and placed in lamps. On page 92 I find an incandescent conductor made from paper cut in the form of a flat ring, carbonized, and a small piece of the carbon cut out so as to leave two ends to the imperfect ring. These ends were fastened to the leading wires of the lamp so as to put it into the lamp. I next find experiments showing the best way to work and carbonize these lamps. Next I find that we made carbons for incandescent conductors of cotton thread which we bent into shape and carbonized, after which we attached the ends to platinum conductors to be placed in lamps. At the same time we made lamps having carbonized conductors from vulcanized fibre, threads rubbed with tarred lamp black, soft paper, fish line, fine threads plaited together in strands, soft paper saturated with tar, tar and lampblack mixed with a proportion of lime, different kinds of thread, cardboards, cotton soaked in boiling tar. Immediately following this there is a record of some of the lamps above mentioned. Shortly after this I carbonized a great many materials, such as vulcanized fibre, celluoid, box wood, cocoanut hair and shell, drawing papers of different grades, spruce shavings, hickory shavings, bay wood shavings and cedar shavings, rosewood, fish lines, maple shavings, tissue paper, string, cotton, lamp wick, punk, cork and bagging flax. Immediately following is the record of lamps made from some of the before-mentioned pieces, with remarks in many cases of how they lasted or how they were carbonized and how or why they ceased to burn. Then follow some of the different methods of how they were fastened to the platinum wires, in order to secure their good connection at the point of contact. Then follow experiments in methods of carbonizing cardboard for conductors. On page 145 I find a sketch which is about the actual size of carbon conductors, of which there were a large number made, which shows the size of the paper cut from cardboard and its size after carbonization. I find also designs for tools for cutting such paper carbons. Then follow a series of numbers of lamps that were made from this model, with occasional remarks of their being made from different materials. Lamps made from these are shown in design attached to the fixtures which were designed at that time for receiving them. Pages 171 to 179 inclusive contain records of lamp carbons made from different kinds of paper, most of which had impurities in the paper. These are immediately followed by designs of tools that were made to cut such papers. Pages 185 to 211 contain records of lamps made from carbonized cardboards with records of some of the facts connected with them, and in some cases deductions drawn from the experiments. Pages 219 to 223 are a record of about fifty lamps showing their condition before putting in the lamp as regards their resistance and the same condition after they were put in the lamp. Pages 225 and 227 relate to methods of carbonization of the paper for lamps, with remarks that were made at the time. Page 229 relates to lamps made about this time of carbons made from paper cut in circular form. Pages 233 to 237 relate to methods of carbonization and some deductions therefrom. The rest of the book contains methods of carbonization and records of some of the lamps that had been made from paper carbons. The results of the experiments in this book are to the effect that Mr. Edison produced lamps having the requisite conditions that he had been long looking and working for, viz: A high resistance incandescent conductor entirely enclosed in a single piece of glass, from which the air had been exhausted to a very high degree. It does not by any means give a list of all the experiments, but only a very few.

The book above referred to is offered in evidence to be marked "Defendant's Exhibit Batchelor Note Book No. 52, March 7, 1889."

171 Q. You stated something in your last answer as to obtaining a high vacuum in the lamps. By what means did Mr. Edison progress towards obtaining this vacuum?

A. At the time that these experiments were made we had already got what we conceived as a high vacuum. Some of the previous experiments had been made in a vacuum, such as could be got from a common air pump. These had extended back for a considerable time, and all incandescent burners which we had raised to give light in such a vacuum had never been satisfactory to Mr. Edison, as the materials of which the burner was made were liable to oxidation in a more or less degree as the vacuum was good or bad. At the time of these experiments Mr. Edison had made lamps which were entirely made of one piece of glass, and by a long series of experiments he had been able to make mercury pumps which would exhaust the air very thoroughly; in fact, equal to anything that is similarly found in the pumps that are used now for manufacturing lamps.

172 Q. How does carbon compare with metals such as platinum or iridium so far as this liability to oxidation is concerned?

A. Carbon compares very poorly in this regard with the finer metals where the carbon is in the open air or even in a poor vacuum. This was our experience in former experiments where we had but a poor vacuum. A lamp made from platinum, some of which are shown in the first part of that book, would last much longer than a lamp made under the same conditions from carbon. In my testimony given in the interference case in 1881, between Sawyer & Man and Edison, already in this case, I testified to having put incandescent conductors in a lamp in October or September, 1877. From these experiments I remember that Mr. Edison, about that time, had frequently put a current through platinum and platinum-iridium, lighting them to incandescence.

He had experimented with small pieces of carbon in the same manner, but they had lasted such a short time that he asked me to put him a piece of carbon in the lamp and exhaust the air from the lamp, so that he could raise it to incandescence in a vacuum. This I did, but owing to the vacuum being imperfect, they did not last long at the brilliant incandescence that he wished to run them. In the open air this same carbon would not have lasted at all.

173 Q. So long as the vacuum is poor is there any substantial difference in the life of the carbons due to a different nature of the carbon; that is to say, would a filament of gas carbon or of paper carbon or of bamboo carbon have any material difference of life in a poor vacuum?

A. I think a poor vacuum would be fatal to all as a long-life lamp.

174 Q. How long did Mr. Edison continue in the commercial sale or manufacture of paper carbon lamps, to the best of your present recollection?

A. I think, to the best of my present recollection, the paper carbons were discontinued in the early part of 1880.

175 Q. After that time, what proportion of the lamps manufactured were made of paper?

A. I cannot say at present, but I know a very small proportion.

176 Q. At the time of the decision in interference, January 10, 1882, by the Examiner of Interferences, J. B. Church, were any paper lamps being manufactured and sold by Mr. Edison or the Edison Company commercially?

A. There may have been a few paper lamps made for experiment, but the lamps sold to the public were entirely made from other material, bamboo fibre. I may say here that at all times, then and since then, Mr. Edison has been continually making lamps of different materials, but the standard manufacture of lamps at that time, as now, has been and is bamboo fibre.

177 Q. What were the practical reasons, if any, which resulted in the commercial abandonment of paper carbon?

A. Mr. Edison found that he could get better carbons for his purpose from a particular part of the bamboo plant than he could get from paper.

178 Q. What was the trouble, if any, with the paper carbon in its commercial use in lamps?

A. The trouble with the paper carbon, from a commercial point of view, was its average life. This in some of the paper carbons was great; in others it was quite small, owing to defects in the paper, causing small arcs at those points and shortening their life. Their average length of life would not compare at all, however careful we were to cut and carbonize them, with the average life of bamboo fibre when properly selected.

179 Q. What was the nature of the trouble caused by the formation of internal arcs in the paper carbons?

A. In the lamps made from carbonized paper, wherever there was a slight defect in the paper, at this point the continuity of the lamp carbon would be lessened as far as the carbon is concerned, owing to the imperfection in the paper being due to some other substance. This would increase the resistance of the carbon at that point to such an extent that it would amount almost to an arc, and we generally saw it whilst the lamp was burning, especially if we only lighted it to a dark red, in the form of a brighter spot at that point than on any other part of the filament. Paper carbons are also defective for lamps by reason of their blackening the globes, owing to the carbon being deposited from the filament on the glass. In Exhibit Batchelor Book 52, my records frequently state that the lamps broke at a certain place or were "busted" on the pumps. These we frequently examined under the microscope, and many of them we thought were due to imperfections in the paper. In cutting the paper we always took great care to select those portions of the paper that did not show any defect to the naked eye; but it was very frequently the case that the defect might be inside the paper, causing the point of high resistance and destruction of the lamp all the same.

180 Q. Do you know of any lamps on the market having carbons of paper?

A. No, sir.

181 Q. So far as your knowledge extends, is the use of paper as a carbon for an incandescent electric lamp of any recognized value at the present day?

A. The use of paper carbon in a lamp for an incandescent conductor is so much poorer than bamboo that I believe that there are no manufacturers or sellers of it in the world to-day.

182 Q. Was there anything in the use of paper carbon as such that suggested to Mr. Edison or yourself the use of bamboo fibre, or the particular quality of bamboo fibre that you finally adopted?

A. There was nothing in paper carbon that was essentially better than anything else carbonized to make a carbon from, except that it was an easy and cheap method of being able to manufacture. It was by no means such a carbon as we have now, which by nature is almost perfectly solid, much smaller and perfectly uniform, which the imperfections of paper never would allow us to get.

183 Q. What experiments has Mr. Edison made from time to time as to the suitable material for use in incandescent lamps?

A. Mr. Edison's experiments have been very extensive. I have made lamps for him from almost every conceivable fibre; from almost all the woods, for some of which I have designed expensive machinery before making them. Mr. Edison's experiments on the grasses and bamboos have been very extensive. He has sent a number of men to different parts of the world, at great expense, who would continually send him large batches of different fibres and different woods, which we would select from and make lamps. He has spent a great deal of money in this direction. As I remember now, he has at the present time one man who has been down in the Cauca Valley, in the United States of Colombia, for about a year. He has sent out at two different times men to Buenos Ayres. He has had a man in Mexico; he has sent two different men to Florida and Cuba; he has sent a man to India and Burmah; he has sent a man for 2,000 miles up the Amazon, at one time, and at another time sent two men together for about 2,500 miles up the Amazon, one of them returning and the other one crossing over to the other side of the Continent, and he is the man who is now in the Cauca Valley. And this has been done at an enormous expense, as his books will show. These men have all sent back large lots of samples of various woods, which have been put through tests sufficient to find their availability for incandescent lamps. I should mention, also, a man that he sent to Japan, China and the Malay Island.

184 Q. Have you experimented with exogenous woods, and, if so, what have you found to be their value in actual use in an incandescent lamp such as you manufacture or have manufactured since the beginning of your business?

A. The use of such woods is very poor for an incandescent lamp. To get a perfect carbon from such woods is almost impossible, owing to the fact that there are cross fibres running around the wood, which you are obliged to cut in cutting lengthwise with the grain. Wherever such a fibre is cut it leaves a bad place in the carbon, owing to the fact that that fibre is partially hollow and lessens the cross-section of your fibre at that point; and in such woods you have a fault similar to what I mentioned in the paper carbon, which would cause arcs, but very much more so than in the paper carbon. I consider them practically useless.

185 Q. Do you know of any manufacturer who sells lamps having the carbons made of any of the exogenous woods?

A. No, sir; I believe they are not employed by any manufacturer.

186 Q. To your knowledge have they been employed by any manufacturer?

A. No, sir.

187 Q. How many exogenous woods has Mr. Edison, to your knowledge, experimented upon?

A. I could not say exactly, but a great many; I should judge forty or fifty. I made at one time a special machine for him to cut these woods out, and I know we tried a great many of them before giving the thing up, as it was rather an expensive experiment.

188 Q. Were these experiments with exogenous woods on one or two lamps, or on how many?

A. I should judge as many as forty or fifty of them, using different kind of wood.

189 Q. Exclusive of bamboo, are you aware of any wood of any description now being used commercially in the manufacture of incandescent lamps?

A. No, sir.

190 Q. Out of the stem of a bamboo how much have you found practically and commercially available for the manufacture of carbon filaments?

A. There is a very small portion of the bamboo that is practically available for the purpose of making a commercial incandescent lamp. This is the most solid part of the wood, right next to the silicious cuticle, and although the thickness of the shell in some cases is as much as an inch, we can only use a few thousandths of it next to the scale. I would also say that of all the many kinds of bamboo that there are in existence there are only a very few that we can make such carbons from, and these could be very soon spoiled for our purpose previous to their getting to us if they were not of a certain growth and seasoned in a proper manner.

191 Q. Have you found by experiment that bamboo has to be cut in any special manner in order to form suitable filaments?

A. We had to design, for making the fibres from bamboo filaments, special machinery to cut that part out of the bamboo filaments that was good for our use; afterwards to take the scale off of it, and then to cut the fibre lengthwise in such a manner as never to split or cut through a single fibre on the outside. The necessity of this was discovered by Mr. Edison when we found that the finest bamboo that we can get is only made up of a number of single fibres very close together, and if we should cut one of them across it would materially lessen the availability of that particular piece of bamboo for use in an incandescent lamp. This we tried to avoid, as after it has been carbonized it has cost considerable money, and all that money would be thrown away if we should find out afterwards, when it was in the lamp, that it had been spoiled in cutting. These things, and many other peculiarities of manufacture necessary to a successful carbon, even from bamboo, we had to find out by a long series of experiments.

192 Q. What do you mean by your answer in regard to the necessity of proper seasoning of the bamboo?

A. In the early part of these experiments we had, along with samples of bamboo, also samples of the same bamboo that were of different growths as regards age and also the different lengths of time that they had been seasoned, and it was found that the filaments which came from the same bamboo were not as good when of some age or of some particular method or time of seasonas others, and experiment told us which were the best. After knowing this we gave our orders for our fine strips of a certain age and a certain seasoning, and that is done, I believe, to the present day.

193 Q. How many endogenous woods and grasses has Mr. Edison experimented upon, to your best recollection?

A. Several thousand.

194 Q. Out of these several thousand how many were practically available, so far as their electrical qualities were concerned, for a filament for an incandescent lamp?

A. There are very few indeed that I could call available for an incandescent lamp. Some of them, although pretty fair, are too difficult to manufacture. Others, while pretty fair for pretty short lengths, cannot be got out for long lengths. I should say that the bamboo, and one or two others, are about all that can be used, that we know of, commercially. Some of the fibres are so loose and have so little carbonizable matter between them that when carbonized that they will split apart. Others are so coarse grained, or the cell wall so small in proportion to the size of the fibre, that it is practically impossible to make lamps from them. We had to find out all these things by experiment. The wood would look all right to the eye to cut filaments from, but something would be there, so that when carbonized, we got an entirely different result from what we expected, the cause of this being, in many cases, undiscoverable, but arising, probably, from some peculiar chemical constituent in the wood.

195 Q. Was any substance known or described generally in the art, on January 9, 1880, as "carbonized paper covered with powdered plumbago?"

A. No, sir; I know of none; I never heard of it.

196 Q. Is it practically possible, in any ordinary sense, to cut out a filament of carbon, such as is used in the Edison lamps, from carbonized paper?

A. It is practically impossible. The carbon cut from carbonized paper from such extreme thinness as would be required for a filament similar to the Edison incandescent lamp filament to-day, or at any time, would be an exceedingly difficult mechanical operation. Its liability to fracture during the operation of cutting would be so great that I doubt very much whether I myself, who am very expert at anything of that kind, would be able to cut more than one in a hundred, and I should not consider it could possibly be anything like as regular and uniform mechanically, not to say electrically, as our present fibre.

197 Q. Are you, and were you, on January 9, 1880, acquainted with the general state of the art in relation to electric lighting, and in particular, to incandescent electric lighting?

A. Yes, sir.

198 Q. In view of the general state of the art at that date (January 9, 1880), would a direction to use wood carbon or charcoal as an incandescent arc or burner in a lamp be of any value as a guide or index to the selection of a suitable arc or burner, or have any value as an aid to the manufacture of a suitable arc or conductor?

A. No, sir; not at all.

199 Q. Is there any quality known to you in wood carbon, as such, which in any way adapts it, as compared with other carbons, for use in an incandescent lamp?

A. No, sir. Out of all the woods that we have tried we had to find out a peculiar property that is only applicable to a very few of the very many woods that we tried. If wood carbon had been suggested to us it would have given us no clue at all, in the state of the art at that time, to the existence of these qualities that Mr. Edison had to find out with so much experimenting.

200 Q. Similarly I ask you whether in view of the general state of the art at that date (January 9, 1880) a direction to use an arc or burner for an incandescent lamp, of wood charcoal, would have been of any value or assistance as a guide or aid in the manufacture or selection of a proper arc or burner for an incandescent lamp?

A. Such a suggestion would have been no use at all, as the natural meaning of such a suggestion at that time would have been the use of an exogenous wood, such as willow charcoal, or charcoal made of box wood or other such woods. Mr. Edison and myself, by reason of our private experiments, had probably gone much further than the general state of the art at that date, and even with our knowledge from our experiments such a direction would have been of no value, for, as already testified to by me, we have never succeeded in making an incandescent lamp, having an exogenous wood as the arc or burner which could by any stretch of language be called a commercial lamp?

201 Q. In view of the general state of the art at the same date, would a direction to make an incandescing arc of carbonized fibrous material have been of any value as an aid or guide to the manufacture or construction of a proper incandescing arc or burner for an electric lamp at that date?

A. No, sir; for the reason, as I said before, that it was only by tedious experiment we found those particular qualities in certain materials that proved to be of value. The term "fibrous" would apply not only to vegetable matter, but to animal matter, and if used in the broadest sense, would cover almost the entire kingdom of organic substance, and out of this enormous mass of material it would be impossible to select a suitable incandescing arc or burner, except by such experiments as Mr. Edison actually conducted, in which the peculiar qualities adapting a substance to incandescing lighting might be determined. The fibrous quality of many materials is the very quality which actually destroys their value for incandescent lighting, owing to their sinuosity and the fact that the fibrous nature differentiates one portion of the material from the other, causing a difference of electrical resistance between one portion of the material and the other, and so a tendency to disruption. This is the case with nearly all grasses and with nearly every wood or woody material that we have experimented upon. I do not mean to say that all these materials would be absolutely useless—that is to say that they could not be rendered incandescent—but that in any ordinary sense, considering the fact that they are to be used in a lamp for practical use to give light, they are of no commercial value.

202 Q. How did you ascertain the fact that in certain woods the fibres were so arranged or of such a character or nature as to be injurious electrically to the life of an incandescent burner?

A. By the use of the microscope, either before the lamp was made or after the lamp had proved bad. We were led to the use of the microscope after our experiments had continued some time.

203 Q. In view of the general state of the art at the same date (January 9, 1880), what value, if any, would there have been to you in the mention, in a specification, that the inventors had tried carbonized paper covered with powdered plumbago for use as an incandescent arc or burner for an electric lamp?

A. Absolutely none. I do not see for what reason they should cover the carbonized paper with plumbago. If they already had carbon it could do it no good to cover it with plumbago. If they wanted a greater surface, or a greater amount of carbon, they could have taken a little thicker paper and got the same result. As I have already testified, paper already carbonized I had put in a lamp for Mr. Edison previous to this time, and it would have been of no service to me, in the making of a better lamp, to have told me to put plumbago on to it.

———

New York, March 8th, 1889.

Met pursuant to adjournment.

Present—Amos Broadnax, Esq., for Complainant; Walter K. Griffin, Esq., for Defendant.

Charles Batchelor, being further examined by Mr. Griffin, testified as follows:

204 Q. Please examine the patent in suit, with the specification and drawings, and state whether, to your knowledge, lamps of the construction shown in said patent are now, or at any time, to your knowledge, have been used practically and commercially, or offered for sale in the market?

Objected to as incompetent and immaterial.

A. I know of no lamp, such as is shown in this patent, having been offered for sale in the market; I have no knowledge of any such lamps having been used commercially in incandescent lighting.

Answer objected to as irresponsive.

205 Q. Have you any knowledge of the use of such lamps practically for other electric lighting than incandescent?

Objected to as incompetent and immaterial.

A. I have not.

206 Q. Examining the said specification and drawings, and further examining the specification and drawings of Letters Patent No. 205,144, to Sawyer & Man referred to in the patent in issue, please state whether you find there shown a lamp chamber wholly of glass

Objected to as incompetent and immaterial.

A. I do not.

207 Q. Why do you consider that the lamp chamber shown in the patent in suit (and in patent No. 205,144, to which I referred you) is not wholly of glass?

Objected to as incompetent and immaterial.

A. Because the lamp chamber A is placed on the glass disc B having a slight coating of fir balsam or some cement between them; also at another place L, on the glass plate B, the patent says that he uses some cement and tin foil between the glass stopper and the plate B. If the chamber was entirely of glass there would be no other materials forming any part of the walls of that chamber.

208 Q. Fir balsam is Canada Balsam, is it not?

Objected to as incompetent and immaterial.

A. That is what is generally supposed.

209 Q. Assuming the lamp shown in the patent in suit, and Letters Patent 205,144, to be lit, and in actual operation, what would be the effect of the heating of the lamp upon the fir balsam or other cement used to connect the base with the globe of the lamp?

Objected to as incompetent and immaterial.

A. It would tend to soften the same.

210 Q. How is Canada fir or Canada balsam affected by heat?

Objected to as incompetent and immaterial.

A. Canada fir or Canada balsam is made more fluid by heating.

211 Q. Assuming the lamp shown in or referred to in the patent in suit to be filled with a gas, as for example nitrogen, what would be the effect of rendering the lamp incandescent, upon the cement joint between the base and the globe of the lamp?

Objected to as incompetent and immaterial.

A. The heat produced by the incandescence of the lamp would, in my opinion, expand the gas, thus putting a greater pressure on the inside of the lamp than on the outside. This heat continued would soften the Canada balsam, and there would be a tendency of the rarified gas to get out at the most imperfect part of the joint. The reverse would be the case after the lamp was extinguised, except that in that case the atmosphere would tend to get in.

212 Q. In your opinion would the expansion and contraction of the glass base and the bell of the lamp be uniform, or vary; and what effect, if any, would such contractions and expansions have upon the cement used to connect the base and the bell, and upon the clamps fastening the base?

Objected to as incompetent and immaterial.

A. I do not think that the difference of expansion in the glasses would make very much difference in the lamp; but the continual heating and cooling of the interior of the lamp would tend to make a bad joint at their point of contact.

213 Q. Have you had any practical experience and knowledge of the art of fusing glass for the purposes of incandescent lamps?

Objected to as incompetent and immaterial.

A. Yes, sir. I have superintended the making of most of the processes that are used in the Edison lamp factory for this purpose. I have also built, and ran for some three years, a large lamp factory in France ; and my knowledge on this subject, although not an expert glass-blower, is considerable.

214 Q. In your opinion is it practically possibly to fuse together a glass disc or plate, and the flanges of a glass globe, such as is shown in Figure 5 of the patent in suit?

Objected to as incompetent and immaterial.

A. It is practically impossible to fuse the two pieces of glass shown in No. 317,676, without damage to the globe.

215 Q. What is the reason of this ?

Objected to as incompetent and immaterial.

A. The reason of this is that the thin glass fusing, the globe will cool off so much quicker than the large portion, that when the whole is cold some parts of the glass will be under tension. In nine cases out of ten it would crack almost immediately after it was cooled; and if not then, a very short time afterwards.

216 Q. Referring you again to figure 5 of the patent in suit, and to Letters Patent 205,144, mentioned in said patent, and to the explanation in the specifications of these two patents of how the metal tubes are closed by metal caps, state whether or not, in your opinion, it is practical to close such a lamp chamber so as to maintain such a vacuum as is suitable for a practical incandescent lamp ?

Objected to as incompetent and immaterial.

A. I do not think that the method shown in either of these patents is suitable for closing a lamp chamber for a practical commercial incandescent lamp. I do not see that in either case they could get anything more than a vacuum similar to what could be got in an ordinary common air pump. They certainly could not exhaust it to such an extent as in any commercial incandescent lamp that is at present on the market.

217 Q. In your opinion, and from your experience would it be possible to maintain any efficient vacuum in a lamp such as is shown in the patent in issue, if the glass disk were ground so as to fit smoothly against the flanges of the glass bell, and clamped, however tightly, without any connecting cement?

Objected to as incompetent and immaterial.

A. In my opinion it would be impossible to keep such a vacuum under the conditions under which an incandescent lamp has to work.

219 Q. Referring you again to the lamp shown and described in the patent in suit, would there be any advantage in the use of a fibrous or textile carbon or a carbon made from fibrous or textile material, as compared with the use of hard carbons ?

Objected to as incompetent and immaterial.

A. I do not see any advantage to be gained, except that it might be easier mechanically to work it.

220 Q. Is there, or was there, in view of the state of the art on January 9th, 1880, any difficulty in making artificial carbon pencils, such, for example, as the Carré pencils of the dimensions similar to or identical with the dimensions of the carbon burner shown in the patent in suit ?

Objected to as incompetent and immaterial.

A. I believe there was no difficulty in making such; but the particular carbons here do not seem to me to be round.

221 Q. Is, or was there any material difficulty in manufacturing artificial carbons of such material as the Carré pencils are composed of, of the size and shape shown in the patent in suit ?

Objected to as incompetent and immaterial.

A. The Carré carbons are generally made round, but the plastic material when in such a state could very easily be squirted through a die having a rectangular section, and previous to their being baked, small portions of these could be taken and bent into the form of an arch, and placed into a lamp similar to that in the patent in issue.

222 Q. Can you tell from the drawings of the patent in suit the nature of the electrical system (exclusive of the lamp) in which the lamp shown is intended to be used?

Objected to as incompetent and immaterial.

A. If the patentee had ever intended to work more than one of these lamps from a machine commercially he certainly must have intended to work them in series. He certainly could not expect to distribute light over a section of a city, with such a lamp as that in multiple arc, which is the generally recognized method of doing so.

223 Q. Where lamps in series are used, is it an advantage or disadvantage to have the resistance of the incandescing conductor high?

Objected to as incompetent and immaterial.

A. It should be as low as possible.

224 Q. How does the resistance of incandescent conductors, say of paper carbon, compare with similar conductors of gas retort carbon?

Objected to as incompetent and immaterial.

A. To the best of my knowledge carbons made from paper carbonized would have considerable more resistance than would what we call hard carbon, when both have the same cross-section and length, even when the carbonization is the most perfect.

225 Q. Returning to the subject of the carbonization of materials for incandescent conductors, state what precautions or conditions you found necessary in practice in order to manufacture paper carbons of suitable character for incandescent conductors?

Objected to as incompetent and immaterial.

A. There are many conditions to be attended to in order to produce paper carbon for an incandescent conductor of a lamp that will be good commercially. I believe in our exhibit yesterday (Book No. 52 which was put in evidence) many of these conditions are enumerated; but briefly, I will give my recollection of some of them. It is very necessary that the carbon should be straight after carbonization. It is also necessary that its shrinkage should be uniform all through. It is necessary that its uniformity should be so great that their electrical resistances are about alike. It is very necessary that you should take a certain amount of time in making such carbonization, as, if it is done too quickly, all those hydro-carbons which become gaseous below about 700 or 800, will be driven off, and tends to rupture whatever is left in getting out; whereas, they ought to be left in to produce better carbon by their own interlocking of the remaining particles. A carbon made by carbonizing paper in a furnace that is already very hot, and in which the carbon is brought in a few minutes to a white heat, would be practically useless, and its resistance would be very much greater than if it was brought up to a certain heat very slow, and only to a white heat after it had been hot for some time.

226 Q. Were all forms of paper suitable for the manufacture of incandescent conductors?

Objected to as incompetent and immaterial.

A. No, sir; there are very many forms of paper that are quite unsuitable. Most forms of cardboards are heavily loaded with oxides of one metal or other. I presume to give them a better finish or to weigh heavier; and these are very unsuitable.

227 Q. Is blotting paper suitable for use as an incandescent conductor when carbonized?

Objected to as incompetent and immaterial.

A. I should not consider it at all suitable.

228 Q. In the carbonizing of paper carbon, what was the effect, if there was any, of unequally heating the different parts of the filament during carbonization?

Objected to as incompetent and immaterial.

A. The effect would be that some parts of the carbon filament would have more resistance than others. This would be detrimental to the lamp, as it would give "spots" in the filament that would be brighter than others, and consequently shorten its life.

229 Q. In the carbonizing of paper, did you find it necessary to use any means to preserve the tension or strain of the fibres composing the paper?

Objected to as incompetent and immaterial.

A. Yes. As I have already stated, it was necessary to bring them out straight and uniform. In order to do this, we had determined, by experiment, that it was necessary to put a weight on each carbon, or a given weight for a total number of carbons, whilst they were in the mold, and heating up in the furnace. Our method of carbonization to accomplish this result generally was to place some sheets of thin paper that we did not want to use as carbon, on top of which we placed paper intended for a filament; after which, a few more sheets of paper, and then another filament; and so on quite a number of carbons intended for filaments. At other times, we had a single weight for a single filament. These were our practical and cheapest methods of getting the desired result.

230 Q. Do you find any statement in the patent in suit, or in the original specification filed January 9, 1880, which, as the art stood at the date of said original application, was, or would have been a sufficient description to enable a proper paper to be selected for an incandescent electrical conductor without experiment?

Objected to as incompetent and immaterial.

A. I do not. I find no description of preparing paper carbons, except that where it is said that they are confined in retorts, in powdered carbon. In fact, the patent and the specification in question, leave it entirely to the skill of the man who is going to make the lamps to find out which is the best method. Certainly, long before the application of January 9, 1880, we had discarded in our own experiments, and for carbonizing for commercial lamps, the only method that I see here described.

231 Q. My previous question was intended to refer, not to the method of carbonization, but to the selection of a proper paper before carbonization. Do you find, either in the patent in suit or in the original specification any direction which, in view of the general state of the art at the date of the application of January 9th, 1880, was sufficient to enable one conversant with the art to select a proper paper for an incandescent electrical conductor, without experiment?

Objected to as incompetent and immaterial.

A. I do not.

232 Q. As a matter of actual fact, how did Mr. Edison and yourself arrive at the selection of a paper which could be used as an incandescent conductor?

Objected to as incompetent and immaterial.

A. By long continued experiments, made with a very large number of different kinds of paper.

233 Q. Do you find in the original specification of the patent in suit filed January 9, 1880, any descrip-

tion of how the paper intended to be used is to be carbonized?

Objected to as incompetent and immaterial.

A. I do not.

234 Q. Is there anything in the original specification which indicates to your mind that the paper was intended to be shaped or cut into form before carbonization?

Objected to as incompetent and immaterial; and also that the original specification is itself the best evidence.

A. There is not. There is nothing in this original specification that I can see that would tend to show me that any of these substances that were used were shaped in the form before carbonization.

236 Q. What, at the date of the application of January 9th, 1880, was understood in the art by the term "carbonized paper"?

Objected to as incompetent and immaterial.

A. The term "carbonized paper" previous to the date of the application of January 9th, 1880, by us at any rate, was applied to paper that had been put into a closed chamber with powered carbon and raised to a red heat in the furnace or fire.

236 Q. Did the term "carbonized paper" at that date mean, in view of the general state of the art, paper already carbonized, or paper to be carbonized?

Objected to as incompetent and immaterial.

A. Paper already carbonized.

237 Q. You have mentioned various conditions of carbonized paper essential to the manufacture of a paper incandescent conductor. How, as matter of fact, did

Mr. Edison and yourself ascertain these necessary conditions of carbonization?

Objected to as incompetent and immaterial.

A. By a large number of experiments previous to this time. I know of no literature on the subject that was given out at that time from which we could gain any information more than what was already generally known.

238 Q. In the original specification is there, in your opinion, in view of the general state of the art at its date, any sufficient description to enable one skilled generally in the art to properly carbonize a paper conductor for an incandescent lamp?

Objected to as incompetent and immaterial.

A. The original specification gives no information that would indicate to a man skilled in the art how he should carbonize a piece of paper in order to make a proper carbon for an incandescent lamp.

239 Q. In using woods for incandescent conductors for electric lamps, what would be the effect of cutting the conductor, and especially of cutting a filamentary conductor across the grain of the wood?

Objected to as incompetent and immaterial.

A. I think it would be entirely impracticable to do such a thing.

240 Q. What would be the effect of similarly cutting a conductor at an angle to the grain?

Objected to as incompetent and immaterial.

A. A similar effect would be caused in this case, but not to so great an extent.

241 Q. What practical effect would this cutting at an angle to the grain have upon the life of such a filament as has been and is used in the Edison lamp?

Objected to as incompetent and immaterial.

A. The practical effect of cutting across the grain of the filament used in the Edison lamps would be to very materially lessen their life.

242 Q. In carbonizing bamboo for the filaments in the Edison lamps, has it been found necessary to use special means of carbonization, or has it been possible to use the general means known in the art on January 9th, 1880?

Objected to as incompetent and immaterial.

A. There is nothing that is generally known in the art of carbonizing on January 9th, 1880, that is being used to-day in a commercial Edison lamp.

243 Q. Had Mr. Edison or yourself, prior to January 9th, 1880, made any special experiments as to the carbonization of paper by methods not generally known in the art?

Objected to as incompetent and immaterial.

A. Yes. I believe that our methods of carbonization for the purpose of incandescent conductors for electric lights were known only to ourselves.

Cross-examination by Mr. Broadnax:

244 x-Q. Referring now to "Defendant's Exhibit, Batchelor's Note Book, No. 52;" was this book referred to in your examination in the interference case—I mean in the interference case between Sawyer and Man on the one side and Thomas A. Edison on the other?

A. I do not think it was referred to during my testimony in that case.

245 x-Q. How recently have you read your deposition in that case?

A. Within the last few days.

246 x-Q. And you do not find in that examination any reference to this book, as I understand you?

A. No. I may say that I have just cursorily glanced over it again, and I find no reference to it in my testimony.

247 x-Q. In whose handwriting is this book?

A. Almost entirely in my own.

248 x-Q. You stated, in answer to question 168 of this deposition, that the book "refers principally to experiments that I carried on for Mr. Edison, in the latter part of 1879." From what period in 1879 does the book refer to experiments carried on by you for Mr. Edison?

A. From July 31st, 1879, to the end of the year. I find the date here, January 2d. 1880.

249 x-Q. If there is any part of it which is not in your handwriting, please designate such parts?

A. The following parts are not in my handwriting: Page 1, the intials T. A. E. are in the handwriting of Thomas A. Edison. The next page is all in my handwriting except the initials T. A. E. in Edison's writing. Page 5, the first 13 lines are in Edison's writing; the remaining four are in my handwriting. The date and my name are in my handwriting at the top, and the initials T. A. E. are in Edison's writing. Page 7 is entirely in my own handwriting except the initials T. A. E. Page 9 is entirely in my handwriting except the initials T. A. E. in Edison's. Page 11, all the writing on this page is in the handwriting of Thomas A. Edison. The drawings on this page I believe were made by myself; 13 is entirely in my handwriting except the initials T. A. E. in Mr. Edison's handwriting; 15, drawings and writing entirely mine, except the initials T. A. E. in Edison's handwriting; 17, sketch and writing entirely in my handwriting; the initials T. A. E. in Edison's. Page 19, the handwriting is entirely mine except the initials T. A. E. in Edison's handwriting. Page 21, handwriting entirely mine except the initials T. A. E. in Edison's. Page 23, handwriting entirely mine except T. A. E. in Edison's. Page 25, handwriting entirely mine except initials T. A. E. in Edison's. Page 27, handwriting and sketch entirely mine. Page 29, handwriting entirely mine except the initials T. A. E. in Edison's. Page 31, handwriting entirely Edison's except my name in my own handwriting; 33, sketch and handwriting entirely mine after initials T. A. E.

in Edison's; 35, handwriting entirely mine except initials T. A. E. in Edison's; 37, handwriting entirely mine except initials T. A. E. in Edison's handwriting; 39, handwriting entirely mine except the initials T. A. E. in Edison's handwriting; 41 handwriting entirely mine except initials T. A. E in Edison's; 43, handwriting and sketch entirely mine except initials T. A. E. in Edison's; 45, entirely my own handwriting except initials T. A. E. in Edison's; 47, entirely mine except initials T. A. E. in Edison's; 49, entirely in my handwriting except initials T. A. E. in Edison's; 51, entirely in my handwriting except initials T. A. E. in Edisons; 53, entirely in my handwriting except initials T. A. E. in Edison's; 57, sketches and writing entirely in my handwriting except initials T. A. E. in Edison's; 58, writing entirely mine except initials T. A. E. in Edison's; 61, writing and sketches entirely mine except the inititials T. A. E. in Edison's; 63, writing entirely mine except initials T. A. E. in Edison's; 65, writing entirely mine except initials T. A. E. in Edison's; 67, writing entirely mine except initials T. A. E. in Edison's; 69, writing entirely mine except initials T. A. E. in Edison's; 70, the figures entirely in my handwriting; 71, entirely in my handwriting except initials T. A. E. in Edison's; 73, writing and sketch entirely in my handwriting except initials T. A. E. in Edison's. There is a faint initial J. A. R.; this, however, I do not know the meaning of; 74, the writing, what there is of it, is Edison's; 75, sketches and figures in Edison's handwriting; 76, sketches—I do not know the writing; 77, writing entirely mine; 79, writing entirely mine; 81, writing entirely mine; 83, writing entirely mine; 84, the figures almost all my own, but of no consequence; 85, writing entirely mine. One or two of the sketches mine. The rest of the sketches, the ones relating to carbon spirals, are Edison's; 87, the writing entirely mine; 89, the writing entirely mine; 91, writing and sketch entirely mine; 92, writing and sketch entirely Edison's; 93, writing and sketches entirely mine; 95, writing entirely mine; 97, writing entirely mine; 99, writing entirely mine; 101, writing and sketches entirely mine; 103, writing entirely mine; 105, writing and sketches entirely mine; 107, writing entirely mine; 111, writing entirely mine; 113, sketches entirely Edison's; 115, writing entirely mine; 117, writing entirely mine except the letters "D. N. C., March 23, 1883"; 119, entirely my handwriting; 121, entirely my handwriting; 122, entirely in my handwriting; 125, entirely in my own handwriting; 127, sketches and writing entirely mine; 129, sketches and writing entirely mine; 131, sketches and writing entirely mine except "D. N. C., March 23, 1883"; 132, figures in my own handwriting; 133, sketches and writing entirely mine except "D. N. C., March 23, 1883"; 135, sketches and writing entirely mine except the writing "D. N. C., March 23, 1883"; 137, writing entirely mine; 139, writing entirely mine except the signature of A. P. Poinier.

250 x-Q. Who is he?

A. He was a young man who was experimenting with us at that time. He was one of my assistant carbonizers.

Page 141, sketch and writing entirely mine except the signature of Poinier; 143, sketch and writing entirely mine except the signature of Poinier; 145, sketches and writing entirely mine; 146, disconnected words, I do not know in whose writing; 147, sketches and writing entirely mine; 149, writing entirely mine; 151, writing entirely mine, except the signature of Poinier; 153, writing entirely mine; 155, signature and writing entirely mine; 157, sketches and writing entirely mine; 158, the writing entirely Edison's, except a few figures of mine; 159, writing and figures are Edison's, a few in some one else's hand that I do not know; it is the item, "365x13;" 161, writing entirely Edison's; 163, writing entirely mine; 164, sketch all mine; 165, writing entirely Poinier's; 166 and 167 are two sketches. I am not sure who made them nor what they represent. 168, figures entirely by Edison, relating to electric light stations; 169, entirely my own handwriting, except the addition of 38,000 to 10,000 in figures in Edison's handwriting, and the letters "D. N.

C., March 23, 1883;" 171, entirely in my handwriting; pages 173, 175, 177, 178 and 179 are entirely in my handwriting; 181, entirely in Poinier's writing; 183, sketches and writing entirely my own, except Poinier's signature in his handwriting, T. A. E. in Edison's writing, and J. Seymour in Seymour's handwriting; Seymour was also an assistant; 185, entirely in my handwriting; 187, entirely in my handwriting; 188, numerous sketches made by Mr. Edison; 189, entirely in my handwriting; 191, sketches and writing entirely mine; 192, figures; I am not quite sure of them; they do not, however, denote anything that I know of; 193, sketches with no signature; I am not sure whether they are Edison's or my own; 195, entirely in my own handwriting; 197, unfinished sketch, I am not sure whether in my hand or not; 198, sketches and writing in Edison's handwriting; 199, the sketch I do not know; 200 and 201, immaterial sketches, no signature, and I do not know who they were made by; 203 I believe is in Seymour's writing; the first part of it has been written backward, so I am not quite sure; I recognize the latter part; 205, entirely in my own handwriting; 207, sketches and writing entirely mine, except Poinier's signature in his own: 209, entirely mine, except Poinier's signature in his own handwriting; 211, entirely in my own handwriting; pages 212, 213, 214 and 215, sketches with a few figures all in Edison's handwriting; 219, entirely in my own handwriting; 220, sketch made by me; 221, entirely in my own handwriting; 223, entirely in my own handwriting; 225, entirely in my own handwriting; 226, figures in my own handwriting; 227, entirely in my own handwriting; 229, entirely in my own handwriting; 230, sketches; I do not know whose they are; 231, entirely in my own handwriting; 232, figures in Edison's handwriting; 233, entirely in my own handwriting; 234, rough sketches; I am not sure who made them; 235, entirely in my own handwriting; 237, entirely in my handwriting; 239, sketch and writing entirely mine; 241, entirely in my own handwriting; 242, entirely in my handwriting; 244, sketches very much like

Edison's I am not quite sure; 245, entirely in my own handwriting; 247, sketches and handwriting mine; 248, figures all in Edison's writing; 249, figures, all of them Edison's; 250 and 251, figures, all of them Edison's; 253, sketch and writing entirely mine; 254, figures, Edison's; 255, my handwriting; 256, a few figures that I am not sure of; all the handwriting is of Edison's; 257, entirely in my own handwriting; 258, sketch I believe is Edison's; 261, sketch looks like mine; 262, all my handwriting; 263, all in my handwriting; 264, sketches and writing mine; 266, sketch and writing mine, except the word "these"; 267, writing purposely made indistinct. I do not know who wrote this. It does not relate to anything in regard to paper carbon. 268, sketches; I do not know whose; 270 and 271 sketches; I do not know who made them; 272, sketch and writing entirely mine, except the word "pump" and "30 inch" in Edison's handwriting; 273, sketch I am not sure of; the figures are Edison's; 274, sketch and handwriting mine; also some figures of Edison's near the bottom; 275, a few figures of mine; with handwriting and figures of Edison; 276, sketch and writing entirely mine; 278, sketch and writing entirely mine, with a few figures of Edison's on the bottom; 279, writing and figures on top part of page mine; figures on bottom part of page Edison's; 280, sketches at bottom I am not sure of. That is all.

251 x-Q. The writing and figures on the several pages of this book--are they in lead pencil or in ink?

A. Some of them are in lead pencil and some in ink.

252 x-Q. Please to designate the pages that have the figures and writing in ink?

> Objected to by counsel for defendant, because the book being already in evidence, it is sufficiently apparent upon the face which entries are made in pencil and which in ink; and unless some special object is made to appear, the cross-examination is trivial and immaterial; if any object material to this inquiry is stated no objection will be made.

Counsel for complainant states that it appears that great deal of the writing is in lead pencil, and being so is easily effaced or changed; and he wishes it therefore to appear on the record so that in case of the book being lost or mislaid, or any question arising as to its contents, it may be determined by the facts on the record.

A. All the pages are numbered in ink. The pages in which the subject matter appears partly or wholly in ink are as follows: 73, 105, 107, 117, 119, 121, 123, 125, 127, 129, 137, 139, 141, 143, 145, 146, 147, 149, 151, 153, 165, 171, 173, 175, 177, 178, 179, 181, 183, 185, 187, 189, 191, 195, 203, 205, 207, 209, 211, 219, 221, 223, 225, 227, 231, 239, 245, 247, 253, 255, and 263. And that is all.

253 x-Q. Why are the pages of this book that are in your handwriting signed by Mr. Edison with his initials?

A. Because Mr. Edison had given me the original instructions to make these experiments, and was keeping watch over them all the time. He would frequently sit down with me and help me for hours. Whenever he saw me entering anything in the book he would generally put his signature to it.

254 x-Q. Do you wish to be understood as saying that the facts noted in this book, whether they are in your handwriting, or in Mr. Edison's handwriting, or in the handwriting of any of your assistants, were noted as of the acts and doings of Mr. Edison himself, the same as if Mr. Edison had made them himself?

A. Yes, sir; the general instructions for all experiments came from him.

255 x-Q. And, as I understand you, the facts in this book are a record of the experiments either made by Mr. Edison himself, in his own proper person, or by you and your assistants, for Mr. Edison, of inventions made by Mr. Edison. Is that correct?

A. They were records of experiments made by Mr. Edison and myself, and my assistants, all of which tended towards carrying out the instructions of Mr. Edison in regard to incandescent lighting.

256 x-Q. And were the experiments noted in that book made at the time that the experiments were noted?

A. In regard to my own signature, it was always placed there on the date that I had finished the experiment, as far as my part of it was concerned. Mr. Edison's signature, wherever it appears, was placed on at the same date as mine, where it appears with mine. Our general rule with all our assistants was to sign the experiments at the time they were making them.

257 x-Q. Are the dates of the several entries given in the book?

A. I do not understand that.

258 x-Q. Is the dates under which the notes were made on the book given in the book?

A. Generally through the book.

259 x-Q. And are the facts noted in the book true?

A. As far as I know they are. Where I have made deductions from experiments they are made from the best knowledge that I had at the time.

260 x-Q. What I want to know is whether the book is a true record of the facts noted, as you understood them, at the time that the notes were made?

A. They are a true record of facts at the time that they were made. They are not by any means the only record, as that book is only one of a large number of books that were used on the same general line of experimenting, but in different parts of the establishment. I will illustrate that by saying that you find very few records in that book of the difficulties or troubles attending the mounting of those particular carbons into their glass globes. This part of the work would be recorded in a book that was kept in the glassblower's establishment. Similarly, not all details of carbonization can be found here; only such as were useful for my purpose to guide me in making another lamp at that particular bench, also the behavior of such lamps on the pumps. You will find only a few of the deductions that could have been made, and have been made in other books, recorded in that book.

The last part of the answer is objected to by counsel for complainant as voluntary and irresponsive.

261 x-Q. How long was it after your examination in the interference case before you found this book?

A. I never found it. The first time I saw it since I went to Europe in 1881 is last Sunday, when it was brought to the laboratory for me to see whether I recognized it.

262 x-Q. At what time in 1881 did you go to Europe?

A. I went somewhere about February, 1881, the first time.

263 x-Q. How long before that did you see this book?

A. I do not remember particularly seeing that book any more than any other of our large number of experiment books after the date of the last record in it. It is very probable that I used it frequently for reference, at the time we were working, on the subject.

264 x-Q. In your answer to question 170 you state that "the latter part of the book consists mainly of lamps with incandescent conductors of carbonized paper, and of these lamps there were a great many made, as many as seven or eight hundred of them being used in Menlo Park at one time. Were these lamps, made of paper carbon as stated by you, good practical lamps?

A. They were very good, practical lamps in the then state of the art.

265 x-Q. But not so good as the lamp of to-day, as I understand you?

A. They were not so good as the lamp of to-day.

266 x-Q. You also state in the same answer, referring to carbons, "These were also made of powdered electric light carbon, which was made into a pasty mass, then rolled up in the form of a thread, carbonized and placed in lamps." Did you consider these lamps also good, practical lamps in the then state of the art?

A. In the then state of the art we did not consider them so good a lamp as we wanted.

267 x-Q. That does not answer my question. Please to answer it categorically, whether the lamps were considered good, practical lamps in the then state of the art?

A. They were better lamps than had been made before. They were not sufficiently practical to put out as a commercial lamp.

268 x-Q. You also state in the same answer as follows, in regard to carbon experiments: "I find that we made these incandescent conductors October 7th, 1879, carbon spirals. These were made from paper tarred—rubbed with tar and lampblack and rolled into the shape of a thread. They were then wound in a spiral form on a special device for that purpose, carbonized, and afterwards put into lamps." How did lamps fitted with these kinds of carbons perform; were they as good as the lamps made of plain paper?

A. They were about the same as the lamps made of plain paper previous to this time.

269 x-Q. Referring now to these paper carbons of plain paper, of tarred paper, and of the pasty material referred to by you, how did they compare with the incandescent electric lamps of the present day?

A. They cannot compare at all.

270 x-Q. They were very much inferior, as I understand you?

A. They were very much inferior, and they were much more difficult to make.

271 x-Q. In the same answer you say, "At the same time we made lamps having carbonized conductors from vulcanized fibre." What do you mean by "vulcanized" fibre?

A. Vulcanized fibre is a material well known in the market, and used by electrical men as an insulator where they do not require such high insulation as rubber. It is practically made by only one or two concerns in Wilmington, Delaware. It is, I think, paper that has been partly parchmentized by treating with chloride of zinc, and pressure, and is generally a hard, compact mass.

272 x-Q. In the same answer you say that you also

made carbonized conductors for your lamps from "threads" rubbed with tarred lampblack, soft paper, fish line, fine threads plaited together in strands, soft papers saturated with tar, tar and lampblack mixed with a proportion of lime, different kinds of threads, cardboards, cotton soaked in boiling tar." How did these lamps perform; were they then considered by you as good, practical lamps?

A. They were not considered by us as commercial lamps in any sense. They were simply lamps made in a long line of experiments that we had to do for Mr. Edison.

273 x-Q. I do not ask you about commercial lamps; I ask you about practical lamps?

A. My only idea at this date of the practical value of a lamp is its commercial value. A lamp, however good, is not commercial unless it can be used generally by the public, as we use our lamps to-day.

274 x-Q. That is what you mean, then, if I understand you, when you say a "practical lamp," or when you speak of a lamp as being a "practical lamp," in connection with your last answer?

A. Some of the above lamps may have been practical lamps if they had been followed, but in the light of to-day I should not consider them, as they burned then, practical lamps.

275 x-Q. Did you ever follow up the making of any of these lamps by actual experiments to ascertain whether they could be made good practical lamps, using the word "practical" as you have defined it?

A. Mr. Edison, I believe, has made many experiments on just such materials as these, and some of these are dated far into the time when he had a much better, and a commercial lamp. My experiments did not carry me further on some of these than just sufficient to show what is now shown in this book. You will notice that the thread lamps are carried quite extensively; but after a really commercial lamp was ready for the market I gave very little attention personally to making experiments on the old substances

that we had proved by experiments were not so good as we had got at a later date.

276 x-Q. You also state in the same answer that "Shortly after this I carbonized a great many materials such as vulcanized fibre, celluloid, boxwood, cocoanut hair and shell, drawing papers of different grades." How did the lamps made with paper carbons perform? Were they considered good practical lamps?

A. Many of the paper carbons that are spoken of in this book made good lamps at the time. As long as we had nothing better we considered that these lamps were good. That we had not got what was the desideratum for electric lighting is shown by the fact that we discontinued such paper lamps very shortly afterwards in favor of other material.

277 x-Q. What material did you adopt as a substitute for the carbons made of paper?

A. The material that we adopted as a substitute was bamboo fibre.

278 x-Q. How did the carbons made from drawing-paper compare with carbons made from other paper?

A. It depended entirely on the kind of paper that we used. You will find in the book that I have shown you a record of anything that occurred to me at the time; and very many of the cardboards that were carbonized proved to be heavily loaded. The best paper carbon loop that we could make would be from absolutely pure paper and cut perfectly even.

279 x-Q. As I understand from your answer the best papers for making carbons for incandescent electric lamps would be paper of pure cellulose as near as you could get it. Is that correct?

A. Paper with the greatest amount of carbonizable matter in it.

280 x-Q. That would be pure cellulose, would it not?

A. Of course there is no paper to be found that is pure cellulose, but the paper which has the greatest percentage of cellulose in it.

281 x-Q. As matter of fact, what kind of an incandescing conductor did the drawing paper make, includ-

ing all the different varieties of drawing paper used by you; did it make a good practical lamp?

A. I cannot give you the results of that experiment at present; I do not find it in the book.

282 x-Q. Which of the papers used by you made the best carbon?

A. The best paper carbon, as I now remember it, was got from thin bristol board of a very pure quality. The tests shown on pages 171 to 179 are tests for papers and cardboards for ash, and some of them are so badly loaded that we could not use them at all. The ones that were not loaded at all were generally the better carbons in the lamp.

283 x-Q. At that time did you succeed in making carbons from the paper mentioned by you, that you then considered good practical carbons?

A. At this time we had made lamps with paper carbons for their incandescent conductors, which we considered at that time as the best lamps that we had so far got. Time alone proved that there were many far superior, which we got shortly afterwards.

284 x-Q. You do not answer my question, which I now repeat: Please state whether at that time you made carbons from the paper mentioned by you, that you then considered good practical carbons; I am referring of course to that time?

A. We considered them more practical than any carbons that we had then made, but that did not deter us from continuing to look for something far superior.

Adjourned to March 9th, 1889, at 10 A. M.

New York, March 9th, 1889.

Met pursuant to adjournment.

Present—Amos Broadnax, Esq., for complainant; Walter K. Griffin, Esq., for defendant.

Charles Batchelor, being further cross-examined by Mr. Broadnax, testifies as follows:

285 x-Q. Do you mean that you had a carbon made of paper that was a fairly good carbon, but did not quite satisfy you, and you therefore continued to look for something better and persevered until you got it?

A. Yes.

286 x-Q. Of what material, in your opinion, can you make the best illuminating conductor for an incandescent electric lamp; I do not, of course, inquire about anything that you or Mr. Edison may have done that is not known to the public?

A. The best conductor for a commercial incandescent lamp that has been tried commercially is, in my opinion, the bamboo fibre.

287 x-Q. And that is a fibrous carbon, so called, is it not?

A. That is a carbon made from fibrous material.

288 x-Q. And in the course of practice and experiments growing out of the invention of the paper carbon, as I gather from your testimony?

A. No, sir. Paper carbon was only one of many substances in that long chain of experiments to get the desired result.

289 x-Q. Which was the first fibrous material out of which you made an illuminating conductor for an incandescent electric lamp?

A. I cannot say which was the first fibrous material that I took to make a carbon for an incandescent lamp, whether of thread or tissue paper. I did not consider the lamp that I made for Mr. Edison in 1877 as made especially by me from fibrous material.

The last part of the answer is objected to by Mr. Broadnax as irresponsive.

290 x-Q. Whatever the fibrous material was of which you made the first incandescent conductor for an electric lamp, as I understand you, you continued from that time on to experiment with different kinds of fibrous material for making illuminating conductors until you settled down on the bamboo carbon?

A. We continued to experiment on fibrous material, but we did not cease to experiment on the other material, as the book will show.

291 x-Q. But you adopted the bamboo as yielding the best results, as I understand you?

A. We finally adopted the bamboo as being the best adapted, as known at the time, to the requirements of Mr. Edison.

292 x-Q. Was it the discovery that an illuminating conductor for an incandescing electric lamp could be made of fibrous material that led you to the long series of experiments of which you have testified to ascertain which of the fibrous materials would make the best conductor?

A. I do not so take it. The bamboo fibre we found after long search had those qualities which were wanted in greater perfection than any other kind of carbon that we had tried before.

293 x-Q. If the discovery that a good illuminating conductor could be made of some fibrous material had not been made, was there anything else that could have led you to make the long series of experiments to ascertain out of which of the fibrous materials the best carbon could be made?

A. I do not think that fibrous material, as fibrous material, gave Mr. Edison much clue to what he was working for. I remember lamps made of lampblack and tar (that was rolled out very thin) that have worked infinitely superior to hundreds of fibrous lamps that were made.

294 x-Q. You have testified that Mr. Edison, and you as his assistant, have made a long series of experiments to get a better illuminating conductor of fibrous material. Now, if the discovery that an illuminating conductor could be made of paper, or similar fibrous material, had not been made, what could have led you to make this long series of experiments?

A. Whether we had ever used a carbon made from paper or not, I think we should naturally have got on to the vegetable growths, because there are so many thousands of different forms, all of which carbons could be made from, and each one of which had its own peculiarity; and from so many thousands of them it was almost a sure thing that we could find some that were good. On the other hand, it is the most likely place to find good carbons in great diversity. The other sources of carbons are rather limited.

The answer is objected to by Mr. Broadnax as irresponsive.

295 x-Q. Is it not true as matter of fact that your investigation in these different kinds of vegetable fibres was entered upon after you had discovered that you could make a good illuminating conductor for an incandescent electric lamp from paper, or some similar fibre?

A. It is true that we got good results from bamboo fibre, after having the knowledge that incandescent lamps could be made with paper carbon; but it does not follow that the paper carbon was a means of our commencing these experiments. I put carbons made from paper into a lamp for Mr. Edison almost two years before, and he did not immediately tell me to make him some bamboo lamps from that. It was only to my mind after a long series of experiments that he found that bamboo had that particular quality that he wanted.

The answer is objected to by Mr. Broadnax as irresponsive.

296 x-Q. At the time that you discovered that a good illuminating conductor could be made of paper, did you not think that you had made a discovery of great value?

A. We thought that we had made a discovery of value; the fact that we abandoned it later shows that we had found something much better.

297 x-Q. At the time you discovered that you could make a good illuminating conductor of fibrous material did you not think (you and Mr. Edison) that you had made a discovery of great value?

A. At the time we were making incandescent conductors from paper we believed that we had something much more valuable than it proved.

298 x-Q. (Last question repeated.)

A. We thought we had made a discovery of value.

299 x-Q. But not of great value, as I understand you?

A. I do not know what Mr. Edison thought about it. I thought it of value; how valuable I did not know?

300 x-Q. Did you think it was worth following up until you had proved its value?

A. We thought it worth while to, and did follow it up, and proved it of no commercial value.

301 x-Q. Do you mean that you proved that an incandescent conductor made of fibrous material possessed no value?

A. No; I mean that we proved to our own satisfaction that paper was not anything like so good a material to make carbon for incandescent conductors, as other things.

302 x-Q. You will please to observe that my question does not refer to paper at all, as a specific form of fibrous or textile material. The question refers only to fibrous material. With this explanation, my question is repeated (297 x-Q. read): "At the time you discovered that you could make a good illuminating conductor of fibrous material, did you not think (you and Mr. Edison) that you had made a discovery of great value?"

A. At the first time that we had made an incandescent conductor of fibrous material, we thought that that discovery had considerable value. I do not know that we attached any of that value to the fact of its being fibrous material. As I have testified before, in answer to question 37 of my direct examination, my

understanding of what Mr. Edison wanted was that the requisite material for his incandescent lamp must have great resistance combined with the least possible surface; and that we were expected to get a substance for an incandescent conductor that would give at least five hundred ohms resistance. I also testified in the same answer that our conversations about that time were frequently directed to getting the highest resistance in the least possible space; and, as I remember it now, I do not believe that the fibrous nature of the carbon entered into the question at all. In fact our experiments show that we had equally as good carbons, at the time of their being made, from non-fibrous material, as from any other.

> Mr. Broadnax objects to, and gives notice of motion to strike out as irresponsive, all of the answer commencing with the words, "As I have testified before in answer to question 37."

303 x-Q. Do you mean to swear that the discovery that illuminating conductors for an incandescent electric light could be made of fibrous matetial, was not a discovery of great value?

A. As far as my knowledge is in regard to conductors for incandescent lamps, I am sure that their fibrous nature as such was not the great discovery in electric lamps. I would illustrate this by the fact that very many, in fact the greatest proportion of carbons for incandescent lamps I have made from woods where the fibrous material was absolutely worthless.

> Mr. Broadnax objects to the answer commencing with the words, "I would illustrate this by the fact," and gave notice of motion to strike out.

304 x-Q. You have testified that at the time that the paper carbons were first made by you, you had made incandescent conductors of other material that were equally as good or better than the carbons made of

paper. Were those carbons made of any of the materials you have mentioned in your examination here?

A. I said, at that time, yes, sir.

305 x-Q. Which of them?

A. I do not remember at this time that a paper carbon was thought any better than some of the ones that I have mentioned, as follows: Vulcanized fibre, threads rubbed with tarred lampblack, soft paper, fish line, fine thread plaited together in strands, soft paper saturated with tar, tar and lampblack mixed with a portion of lime, different kinds of thread, cardboards, cotton soaked in boiling tar.

306 x-Q. All those you have enumerated are fibrous carbons excepting the tar and the lampblack carbon. Did you find the carbon as good as those made of fibrous material in whole or in part?

A. To the best of my recollection those carbons were as good as the others made at that time.

307 x-Q. How many of them did you make?

A. There were only a few of them made at that time.

308 x-Q. Did you ever put out any lamps with such carbons?

A. I do not think so. I presume you mean by "putting out" giving them to the public to use or selling them to the public to use.

309 x-Q. Why did you discontinue the making of such carbons?

A. I do not think that I can say that we have ever discontinued the making of carbons of lampblack and tar.

310 x-Q. How many such carbons have you made in the past two years?

A. I have made none myself during the last two years.

311 x-Q. How many have you made the last five years?

A. I made some carbons, I think, in 1883, at my factory in Paris of such materials to be used to illustrate lamps made on that principle in a lawsuit or interference suit in London.

312 x-Q. You made them by way of experiments?

A. I made them to show that they were practical lamps.

313 x-Q. Commercially practical?

A. Not commercially practical in the sense of our present lamp, but that they would give light and burn for a considerable time.

314 x-Q. How many of them did you make?

A. I think about a dozen of them.

315 x-Q. You made them to use as exhibits in a lawsuit in London, as I understand you?

A. I do not know whether they were used as exhibits, but I made them at the request of either the Edison Light Company of London or of their lawyers.

316 x-Q. Are all of the Edison lamps now put upon the market fitted with illuminating conductors made of fibrous carbons?

A. All of the Edison lamps made by the Edison Company are fitted with conductors made from carbonized vegetable substances.

317 x-Q. Are they cut into form before carbonization?

A. I do not think so. My understanding of them is that they are cut to a shape, then bent into their form and then carbonized.

318 x-Q. You mean by your last answer that the illuminating conductors are made to the desired form and size before they are carbonized?

A. They are made to the desired form and to a certain size; after they are carbonized they are smaller.

319 x-Q. You have testified that since the discovery of the fact that a good carbon conductor could be made of vegetable fibrous material you have spent a great deal of time and effort to ascertain of what fibrous material you could obtain the most satisfactory illuminating conductor. How much time and effort have you spent to ascertain whether an equally good illuminating conductor could be made of materials non-fibrous?

A. In proportion to the variety of conditions of carbon that you can make from vegetable substances to those substances from which you can procure suitable carbons for making incandescent conductors that are not vegetable, I should say that a very large amount of time has been spent in trying to procure a carbon from non-vegetable substances. As we can make carbon from almost all vegetable substances, and as our other sources of carbon in proportion are very much limited, it follows that a great deal more time has been spent in total on those carbons than on those from non-vegetable substances.

320 x-Q. What success did you meet with in your efforts to make satisfactory carbons from non-vegetable substances?

A. As experiments they were successful.

321 x-Q. Were they so successful as to warrant you in putting any lamps on the market provided with such carbons?

A. I do not remember that we have ever put such lamps on the market.

322 x-Q. If you have made any lamps with such carbons since your first use of paper carbons, state if you recollect how many you have made?

A. I have answered this before, in the lamps that I mentioned that I made in Paris.

323 x-Q. Did you ever make any in this country?

A. None except the ones that were made and spoken of in my Exhibit Book No. 52.

324 x-Q. What do you mean by the "bell" of the lamp?

A. If it is in an answer relating to the sketch of the Sawyer-Man lamp, I mean the bell jar or enclosing globe of the lamp.

325 x-Q. Is it your opinion that it is impracticable to fuse a glass disc and the bottom of the enclosing globe or lighting chamber of the Sayer-Man lamp?

A. It is impracticable to fuse the glass disc on to the bottom of the enclosing globe of such a lamp as is shown in the Sawyer-Man patent. I do not say that it is impossible to do so, but, as I testified before, the unequal contraction in the cooling of such a globe after fusion would be very detrimental and a very large percentage of them would crack at the point where the glass is smaller in section than the large plate.

326 x-Q. I do not say anything in my question about the thickness of the glass disc to be fused on the bottom of lamp?

A. I presume that you referred to the lamp that I have testified about, and of which there was a drawing here at the time, in the specification.

327 x-Q. Assuming the glass disc to be of equal thickness with the globe of the lamp?

A. I think that it is then a difficult operation, compared with the ordinary method of sealing the parts of the lamp together.

328 x-Q. Is it your opinion that it would be practically impossible?

A. I do not say that it is practically impossible, but a good commercial lamp would never be made that way, as the state of the art at present gives us much better means.

329 x-Q. At the time that the application for the patent in suit was made, was there any novelty in making the enclosing chamber of the lamp of glass, and then fusing the two parts together?

A. At the time of this application (which is January 9th, 1880), the process for use in an incandescent lamp was novel, and only used to my knowledge by Mr. Edison.

330 x-Q. Was there any novelty in making such a lamp in the summer or fall of 1878?

A. I do not know; I do not remember any such lamp being made in 1878 by anybody.

331 x-Q. Do you not know that the chamber or enclosing globe of any incandescent electric lamp had been made wholly of one piece of glass, having their electrodes passing through holes in the bottom of such lamps?

Objected to as incompetent on cross-examination, not being based on anything in the direct.

A. At what time?

332 x-Q. In 1878?

A. I do not know of any such lamp having been made in 1878.

333 x-Q. Did you read the deposition of Mr. Sharp for the defendant in this case?

Same objection as x-Q. 331.

A. I did not.

334 x-Q. Is it your understanding that the incandescing conductors claimed by the patent in suit are limited to their use in the particular lamp, or form of lamp, described in or referred to by the patent in suit.

Same objection as to the last question and also as immaterial.

A. I have no particular understanding or opinion in the matter as regards its being confined to anything. I find that, although expressed differently, it is practically the same thing as the lamp made by me for Mr. Edison in 1877.

The last sentence of the answer is objected to as irresponsive.

335 x-Q. Was it not old in 1878 to make glass bulbs of the same form substantially of the bulbs or enclosing chamber of the Edison lamp?

Objected to as improper on cross-examination. Not being based on any fact or circumstance brought out on the direct.

A. I do not remember to have seen any globe of that particular shape. I think that those globes were especially made for us, and they have been known as the Edison patent almost always.

336 x-Q. Was it not old in 1878 to seal the leading-in wires for an electric circuit in the walls of a glass enclosing bulb or chamber?

Objected to for reasons last stated, and also that it does not appear that the witness is qualified to speak of the state of the art in the particular respects requested of him by counsel for complainant.

A. It was not old in 1878 to use an enclosing globe having wires sealed into the glass, which wires were connected together by an incandescent conductor.

337 x-Q. (Last question repeated.)

A. If you refer to such specific instruments as Geissler tubes they were known in 1878.

338 x-Q. I do not refer to any particular specific instrument, but simply want to know whether it was old in 1878 to seal an electrical conductor in the walls of a glass enclosing chamber?

Same objection as to x-Q. 336.

A. I think it was old. I have seen such instruments.

339 x-Q. Have you ever read the specification of Mr. Edison making part of the application which was involved in the interference with Sawyer & Man, and as to which you gave your testimony?

A. I have given testimony on it, I presume. I have read it, but I do not recall it to my mind. I would probably know it if I saw it.

340 x-Q. Do you mean by your last answer that you do not recollect of having read that specification?

A. I do not recollect to have read that particular specification at present. If I have testified on it I believe I have read it, but I do not now recall it to mind. (Said specification is handed to the witness.) I have now read the specification referred to.

341 x-Q. Is this the first you have read it?

A I do not think so. I believe I have read that before.

342 x-Q. In answer to Question 237, " You have mentioned various conditions of carbonized paper essential to the manufacture of a paper incandescent conductor. How, as matter of fact, did Mr. Edison and yourself ascertain these necessary conditions of carbonization?", you answered: "By a large number of experiments previous to this time; I know of no literature on the

subject that was given out at that time from which we could gain any information more than what was already more generally known;" do you mean, or did you mean at the time that the notes were made in the book?

A. Yes; at the time that the notes were made in the book.

RE-DIRECT EXAMINATION BY MR. GRIFFIN:

343 Q. Is it within your general knowledge whether or not commercial lamps are commonly on sale, in which the incandescent conductors are made of non-fibrous material; if so, please state what materials you know are commonly understood to be used by manufacturers or venders of incandescent lamps in this country?

Objected to as incompetent and immaterial.

A. It is commonly understood that the U. S. Electric Lighting Company make a lamp of tamadine. This I believe to be a non-fibrous material. I believe also in England I have read of their using lamps from a substance which is non-fibrous, and which is squirted through a die into a liquid which precipitates it. My impression is that these lamps were on the market. Outside of these I do not remember any others.

344 Q. Mr. Broadnax in his cross-examination spoke of Mr. Edison's discovery that conductors of fibrous carbon could be used in incandescent lamps; at the time that Mr. Edison was using paper carbon, did he attach any importance to the fibrous nature of paper, or discuss with you in any way any advantages due to its fibrous quality?

Objected to as incompetent and immaterial.

A. I do not think he attached much importance to its fibrous quality. His conversations with me at the time were always in regard to finding a material or substance from which we could get a carbon that would be practical, of extreme smallness of cross section, with length which would naturally give high resistance. As I understood, whether we got it from one thing or another was immaterial so long as those conditions were there.

345 Q. What is the common and ordinary source of carbon? Is it from vegetable or inorganic matter that it is more generally obtained?

Objected to as incompetent and immaterial.

A. The great source of carbon, in the ordinary expression of the term, is vegetable or has vegetable origin.

346 Q. So far as your experience has gone, has the fibrous quality, so far as the same may exist in vegetable structures, been of any value as such in the construction of electrical conductors for incandescent lamps?

Objected to as incompetent and immaterial.

A. The value that we have found, after long experiments in carbons made from vegetable substances, I believe is more in the fact of their having small filamentary cells packed very closely together, than in anything else. It took us a very long time to find out those peculiar vegetable fibres that would give us perfect continuity, and the most even and dense structure.

347 Q. Have you found, in your experiments, that the presence of the fibrous quality in the woods or vegetable substance used by you, was any indication as to the electrical value of the resultant carbon, when used as a conductor in an incandescent lamp?

Objected to as incompetent and immaterial.

A. No, sir. If we could produce a method of making a carbon, whereby the solid part would be perfectly dense, and still longitudinally it would be cellular, this would be much better than the carbon we now produce from bamboo fibre.

348 Q. As a matter of fact, in all exogenous woods that you have experimented upon, as testified to by you upon direct examination, has the fibrous quality of the woods, so far as it may have existed, been of any value in the formation of a carbon conductor?

Objected to as incompetent and immaterial.

A. In the formation of a carbon conductor from such woods, the fibrous nature of it is absolutely detrimental. In fact it makes them worthless.

349 Q. Whatever the real reason may be as to the peculiar merits possessed by bamboo, as a material for incandescent electrical conductors, as matter of fact do the same merits exist in all vegetable fibrous material?

Objected to as incompetent and immaterial.

A. No, sir; and in all materials that are manufactured, such as paper, thread, ropes and such, they do not exist at all.

350 Q. You spoke of Mr. Edison's search for a material having a high resistance and small surface. Did this search begin before or after the use of paper carbon in incandescent lamps?

Objected to as incompetent and immaterial.

A. It began, as far as I know, long before—when he first discovered that it was possible to subdivide the light by that method.

351 Q. In such vacuums as you had the means of creating, in the earlier stages of Mr. Edison's experiments, was it possible to prevent any form of carbon from oxidization?

Objected to as incompetent and immaterial.

A. Previous to the time when Mr. Edison made lamps having glass globes, hermetically sealed (in the

sense that we to-day know them to be hermetically sealed), nothing would last when used as an incandescent conductor, for any length of time, compared with the life of lamps now, in such vacuums as we could get then.

Adjourned to Monday, March 11th, 1889, at 11 A. M.

CHARLES BATCHELOR.

Sworn to before me,

WILLIAM T. FARNHAM,

[L.S.] Special Examiner and Notary Public.

End of Batchelor's McKeesport Deposition.

UPTON'S McKEESPORT DEPOSITION.

Composed wholly of his two depositions in the Interference Case.

Upton's First Interference Deposition.

Pursuant to adjournment this testimony was continued June 28th, 1881, at 10 A. M., at same place, the same counsel being present.

FRANCIS R. UPTON, a witness produced in behalf of Mr. Edison, being duly sworn, testifies as follows in answer to questions proposed to him by George W. Dyer, counsel for Edison:

1 Q. Please state your age, residence and occupation?

A. Age, twenty-eight; residence, Menlo Park, N. J.; occupation, manufacturer of electric lamps.

2 Q. State whether at any time you went into the employment of Mr. Edison, and what your duties were?

A. I entered the employment of Mr. Edison about

November, 1878. I can fix the date exactly by reference to my accounts, and will do so. My first occupation was making a search through the records of electric lighting in the Astor Library. When this was completed to Mr. Edison's satisfaction I entered his employ at Menlo Park, to assist him in making calculations.

3 Q. What special training or acquirements had you for making such calculations?

A. Before entering college, and while in college, I gave special attention to the mathematical branches. After leaving college I studied two years under Professor Brackett, of Princeton, learning how to use physical apparatus, and becoming proficient in algebra and calculus. After that I spent one year in Berlin, in the laboratory of Professor Helmholtz.

4 Q. Please state now the particular branches connected with the electric light which came under your immediate supervision after entering the employment of Mr. Edison?

A. In the first place I made such calculations as were in my power regarding the electrical conditions necessary in a system of electric lighting in answer to questions asked by Mr. Edison, as for instance, I have the memorandum December 15, 1878, this problem given to me when I first came into the laboratory: "Example No. 1, 100 lamps, 10,000 ohms" (diagram shows lamps in multiple arc); "100 lamps, 1 ohm" (diagram shows lamps in series). "How much heat in each lamp? Heat $= C^2 R$. Answer, the same." This problem is an example of the work I had to do. Besides calculations I assisted Mr. Edison in experimenting, translating and keeping records.

5 Q. At the time of entering into the direct employment of Mr. Edison in the latter part of 1878, what, if anything, was he doing in experimenting and perfecting electric lighting?

A. He was experimenting with the platinum spiral lamp with a thermal regulator. I remember helping to measure the expansion of the heated spiral of platinum. Besides this Mr. Edison was making an extended

series of experiments to find the laws of magnetism. He was also studying publications referring to constructions of dynamo machines.

6 Q. I wish to call your attention to experiments connected with determining the laws of resistance as applied to carbons, particularly those made of paper, and the mechanism and apparatus essential for the production of incandescent electric lighting?

> Objected to by counsel for Sawyer & Man as impertinent.

A. Mr. Edison had me calculate the size and weight of cables necessary to carry the current to a certain number of lamps of given resistance (my impression is 100 ohms) at various distances from the machine, so that a certain per cent. of the energy in the circuit could be used in the lamps. He also had me construct tables, showing the joint resistance of a number of lamps in multiple arc. Mr. Edison concluded that to make a successful electric lamp it should have in the neighborhood of 100 ohms resistance. He tried a large number of devices for obtaining this resistance from metal wire. At the same time he was carrying on experiments with the telephone. In the course of these experiments with the telephone threads of carbon were made. He had these tested for resistance and found them very high. This suggested to him the possibility of successfully making high resistance carbon lamps. He, with the assistance of Mr. Batchelor, made a large number of lamps with carbon filaments. At that time my attention was more particularly drawn to the vacuum pumps, and the construction of dynamo machines. I was employed in testing the efficiency of Mr. Edison's machine, and did not follow all the experiments that led to the paper loop. I recollect when one of the first successful loops was made. Frances Jehl and I measured the resistance, cold of the carbon. My recollection is that it was about 140 ohms. The carbon was burnt for a number of hours and again tested, and no change found in its resistance. This was repeated several times, burning and testing, until the lamp gave out. I remember that we all felt very much elated at the fact of the carbon not changing its resistance, for it showed that there was no wasting away of the carbon. We then felt that it was possible to make a system of electric lighting, simply by adding to the life of the lamp, which we have since done.

7 Q. Of what material were the threads or filaments of carbon made, referred to in your previous answer?

A. My impression is, from ordinary sewing cotton. I recollect that Mr. Batchelor procured from the Clark Thread Works, special samples of cotton thread, afterward.

8 Q. When did you know of Mr. Edison's experiments on conductors made of carbonized paper?

A. I can only recollect now the finished loop, as mentioned in a previous answer.

9 Q. When, to the best of your recollection, did Mr. Edison determine the prerequisite of high resistance for a successful incandescent electric light?

A. Early in 1879.

10 Q. How early was his attention turned to the production of more perfect dynamo machines?

A. He was experimenting on them before I entered his employ.

11 Q. When, so far as you know, did Mr. Edison turn his attention to improved means for producing a vacuum in electric lamps?

A. The first recollection that I have is when he sent me to Princeton to borrow a Geissler pump. I can't fix the date now, but may be able to do so.

12 Q. Did you at any time, under Mr. Edison's direction, experiment on improved means for producing a vacuum in incandescent lamps, and if so, at what time?

A. By his wish I commenced to learn to blow glass. Not succeeding at this, he advertised for a competent glass blower, and the first glass blower was a German from New York, and then a young man by the name of Boehm. I worked with these, helping to the best of my ability in making pumps for producing a vacuum in

incandescent lamps. Before September 16th, 1879, pumps had been made that worked satisfactorily.

13 Q. At the time these means of producing vacuum had been determined had resistance of carbon filaments been determined?

A. I cannot recollect.

14 Q. At this same time had the dynamo machines been satisfactorily perfected?

A. They were perfect enough to make us sure that if a lamp of sufficiently high resistance could be made it could be used successfully in a system of electric lighting.

15 Q. At what date did Mr. Edison produce an incandescent electric lamp fit to compete commercially with gas?

Counsel for Sawyer & Man objects to the question as immaterial.

A. To the best of my recollection it was in November, 1879, when the stable resistance of a paper carbon loop was determined.

16 Q. At that time was the system worked out and the various forms of apparatus essential to carry it into successful use?

Objected to as immaterial.

A. Yes.

17 Q. From the date of your employment by Mr. Edison have you labored constantly and incessantly under his direction in the perfection and production of incandescent lights and the apparatus necessary to make them available?

A. With the exception of about two weeks; yes.

18 Q. When did Mr. Edison first produce for public exhibition his incandescent electric lamps with paper carbon conductors?

A. The next day after the publication of the article in the New York "Herald," which I find here, marked Edison Exhibit No. 2, dated December 21, 1879.

19 Q. Please look at the lamp now shown you, which is marked "Exhibit Edison's Commercial Incandescent Electric Lamp." State whether that represents the character of lamp referred to in your previous answer?

A. Yes.

20 Q. State, if you please, about the extent and kind of use made then and afterwards with that kind of lamp?

A. Wires had been run in the laboratory building. In connection with these chandeliers had been placed so that the light from the lamps could be used while experimenting. Lamp-posts were placed on the road to the depot. My impression is that this was all done before December 21st. The dynamo machines were in place. Mr. Edison was waiting for his foreign patents to be issued, I understood, at the time. Wires were also run to my house and to Mr. Edison's house; in one case using a special line of poles, in the other the Western Union poles. The light was used in the hall and two rooms of my house, for all ordinary purposes, and while tests were being made burned continually and without interruption for several weeks, from dark until ten or eleven o'clock. There were, I think, from sixty to over one hundred lamps in the circuit. While the public exhibitions were given, my duty was to watch the dynamo machines to see that no harm was done them, and to explain to visitors their working and the working of the light. I had a lamp hung over my dining room table, which we used regularly to eat by at night. I remember having a dinner party, with one lamp hung over the table giving sufficient light. This was all done within three weeks after that publication.

21 Q. State, if you please, whether the data relating to these lamps were put in your charge. If so, about what time was it?

A. Mr. Batchelor started the book giving the hours burned of the lamps. The record of the lamps, I notice, is in Mr. Batchelor's handwriting until January 5th, 1880. After that time a young man named Herrick kept the record. I helped him at various intervals while he was keeping the record, examining into the

accuracy of his records, and checking his figures. The record was kept for Mr. Edison, who wished to know the life of the lamps. If the lamps were scattered it required constant watching to make the record exact. The machines were run during the day and night. When Herrick was absent a slip was left for him giving the number of hours which the machines ran. If any lamp broke notice was given him as soon as discovered. All the lamps were numbered, so that they could be recognized. The record I refer to is that from which Edison Exhibit No. 3 is taken.

22 Q. When did you begin to manufacture lamps especially adapted for incandescent electric lights?

Question objected to as utterly immaterial.

A. About November, 1879.

23 Q. From an examination of the record of lamps before referred to, can you state about the average life of the lamp used in the latter part of 1879 and the early part of 1880, at Menlo Park?

Question objected to as immaterial.

A. I think that so much of the record as is printed is a fair statement, though it does not give several lamps that burnt an exceptionally long time. For example, one on the lamp-post at the corner of Mr. Thornall's barn, which burnt from 1,400 to 1,500 hours. I recollect this lamp distinctly as giving a bright light. I recollect examining it to see if the number was on it. I have a tabular statement of the life of these lamps, which I will endeavor to find and put in evidence.

24 Q. Did all these lamps about which you have just testified have carbon conductors made from paper?

A. Yes.

25 Q. Have you continued the manufacture of such lamps since?

A. Yes.

26 Q. What do you know of the sale to and use by

other parties of such lamps—I mean electric lamps with paper carbon conductors?

A. The steamship "Columbia" was fitted out in May of 1880, I think, with about 150 of these lamps. An exhibition was given while the steamer was at the dock in New York, lighting the saloon and a number of staterooms.

27 Q. Was any publication made by you about the last of December, 1879, or early part of January, 1880, about the state of perfection at that time of Mr. Edison's inventions in incandescent electric lamps?

A. I wrote an article about that time which was published in "Scribner's Monthly" for February, 1880. This article is a full description of Mr. Edison's labors to that date.

Article produced, put in evidence, and marked Edison's Exhibit No. 10.

The exhibit is objected to on behalf of Sawyer & Man as incompetent, irrelevant and immaterial, and not legal evidence in any sense.

28 Q. Mr. Man, in his testimony in this interference, speaks of using "principally ordinary blotting paper" for incandescent conductors for electric lamps. Have you had any experience in the carbonization of ordinary blotting paper; if so, with what results?

A. I have had some experience. Carbons made from blotting paper are easily broken and not as durable as carbons made from compressed paper.

29 Q. Mr. Man further testifies in the same interference of "rubbing down and working out by hand the carbons." Have you had any experience in this kind of manipulation of paper carbons?

A. I have never tried the process mentioned. I should judge it to be extremely difficult.

30 Q. Referring to the answer to cross-question on page 18 of the printed testimony of Albon Man, what office would be filled by the interior conductor coated in the manner described?

A. I should say that the paper loop is mostly useful for mechanically holding the solutions with which it is said to be treated, and that the larger portion of the current would be carried by the carbon from the substances with which the loop is treated, so that the greater portion of the light would be given by them. The looser and more porous the paper the less will it carry the current and give the light from itself.

By consent this testimony was postponed until Wednesday, June 29th, 1881, at 10 A. M., at same place.

Wm. H. Meadowcroft,
Notary Public,
New York County.

Pursuant to adjournment this testimony was continued June 29th, 1881, at same place, the same counsel being present.

31 Q. I call your attention to your answer to question 23, and ask if Edison's Exhibit No. 3 gives a correct statement of the life of the lamps therein recorded as not destroyed, and ask you to supplement the history of the lamps which were not destroyed, so as to show their full duration?

A. So far as it goes it is correct, but on examining the records I find that the lamps are continued in another book, for example, lamp No. 159 is continued in book No. 74, copying the original record and carrying the record to January 30th, 1880. The lamp is shown to have a life of 683 hours and 45 minutes.

Lamp 223, which is copied on page 3, burned 367 hours and 17 minutes.

Lamp 155 is recorded as burning 562 hours, 14 minutes; 201 is recorded as burning 638 hours. Lamp 164 is recorded as having burned 640 hours, 14 minutes. Lamp 172 is recorded as burning 638 hours and 14 minutes. I find these memoranda on pages 1 and 2, pages 5,7 and 8, 9 and 10, 11 and 12, pages 13 and 14, respectively.

> Counsel for Edison tenders the above record book for examination to counsel for Sawyer & Man, and puts in evidence copies of the pages above-named, the same being marked Edison's Exhibit No. 11.
>
> Counsel for Sawyer & Man objects to the exhibit as an incomplete copy of the record referred to, and as impertinent, the copy being no evidence unless the record itself is put in.

32 Q. Have you read the printed record of the testimony of Messrs. Sawyer & Man in this interference?

A. The larger portion of it.

33 Q. Where a paper carbon conductor built up in the manner described by Sawyer & Man in their testimony is used in an electric lamp, what special function as regards incandescence is exerted by the paper carbon portion of such conductor?

A. As a mechanical support for holding the solutions with which the carbon is built up.

34 Q. Would not materials other than paper carbon serve for such a support?

A. Yes; asbestos, for instance, in the cases where they dip the loop into solutions, or fiber of any description.

35 Q. I wish you would examine the answer of William E. Sawyer to the 18th question, and the statement about candle power, duration of burners, fracture, &c., and state what results would follow from the various conditions named in his answer?

A. I should judge from the surface of the lamp in Sawyer's Exhibit No. 4, and from the thickness of the carbon, that it might be possible for a lamp to last, giving twenty-five candles, for the time mentioned. The surface, I should think, is twice as great as that in Exhibit Edison's Commercial Incandescent Electric Lamp. Since the economy of a lamp is inversely as the surface, it would take more power to obtain the same light from

the Sawyer, as from the Edison. At the same time the thickness of the carbon is so great that it should also last much longer than the Edison carbon. The resistance of the carbon shown in the drawing must be in the neighborhood of 1 ohm at the most. This, in my opinion, renders the lamp totally uncommercial owing to the enormous loss there must be from conduction through the clamps. For example, the Edison carbon having 100 ohms and the clamp 1 ohm, only $\frac{1}{101}$ of all the energy used by the lamp will be lost in the clamp, while in the lamp, Sawyer's Exhibit No. 4, if the clamp has a resistance of 1 ohm, the same as in the Edison, one-half of the total energy used in the lamp will be lost in the clamps. Besides this, the increase of the size of the carbon allows more heat to be conducted from it to the clamps. As a result, I should judge it would be impossible to seal the lamp unless some device were used to dissipate this heat, making the lamp very large and clumsy.

36 Q. Referring now to the description and sketches given in the printed record of Sawayer & Man's testimony, of the perfected lamp made by them, state whether in your opinion such a lamp would be a practical lamp, and give your reasons?

A. I do not think that it is a practical lamp. The first objection is on account of its low resistance, as stated in the previous answer. Besides the heat at the clamps, owing to the large currents that would have to be employed to give out sufficient energy for light from a small resistance, there would be a great deal of trouble in making the clamp last, as the tendency for arcs to spring between the clamp and the carbon would be so greatly increased.

I do not consider it possible to make such a lamp and hermetically seal it in a glass case, preventing any air from reaching it. Unless this is done, a carbon lamp blackens the globe that surrounds it very quickly. Judging from my experience with notrogen placed in the globe around the lamp, it would be extremely difficult for a carbon to give the same light continuously for a number of hours. I tried for over a week at one time to make a carbon, composed of paper only, burn in an atmosphere of nitrogen, without success.

I took every precaution that Mr. Edison and his chemist, Dr. Moses, suggested to make the nitrogen pure. The experiment was carried on in the bell-jar of an air pump. The air was exhausted from the bell-jar, and nitrogen drawn in. Then again exhausted, and nitrogen again drawn in. I made the nitrogen, holding it in large bags, then, before drawing it in, the bell-jar was dried and passed over hot copper filings. With loops made of paper only no light could be made. I should also say that the lamp, Sawyer's Exhibit No. 4, filled with nitrogen would soon lose it, if lighted many times. When lighted, the gas inside the globe will be expanded, thrusting out the nitrogen. When cold, the outside air will be drawn in to replace the nitrogen. Judging from the style of the lamp, I should say that the gas would be very much compressed when the lamp was lighted, owing to the great amount of heat evolved in a small chamber.

Counsel for Edison gives notice that he here closes his examination of this witness, and offers him to counsel for Sawyer & Man for cross-examination.

CROSS-EXAMINATION BY AMOS BROADNAX, COUNSEL FOR SAWYER & MAN:

37 x-Q. What is your name?

A. Francis R. Upton.

38 x-Q. Have you fixed the exact date, by reference to your accounts, when you went into the employ of Mr. Edison?

A. November 15, 1878.

39 x-Q. Have you been continually in his employ from that time to this?

A. Yes; to the first of January, 1881, when I became superintendent at the lamp factory of which he is chief owner.

40 x-Q. Where is the lamp factory of which he is the chief owner; and what kind of lamps are manufactured there?

A. The factory is situated at Menlo Park, and the lamps are those suitable for his system of electric lighting.

41 x-Q. Are the lamps that are manufactured at that factory substantially like the lamp Exhibit Edison's Commercial Incandescent Electric Lamp?

A. Yes, with the exception that bamboo is used in a large number on account of the ease of manipulating it, instead of paper, for the illuminating conductor.

42 x-Q. Which makes the best carbon for electric lighting by incandescence, paper or bamboo?

A. Bamboo,

43 x-Q. How is bamboo superior to paper for that purpose?

A. On account of the difficulty of procuring paper of even thickness, and because the fibres of bamboo are continuous in the direction in which the current flows.

44 x-Q. How does the resistance of an illuminating conductor made of bamboo compare with the resistance of a similar conductor made of paper?

A. The resistance of the bamboo is slightly less than that of paper.

45 x-Q. In the difference in the resistance of the two carbons sufficient to affect the practical working of the lamp?

A. No.

46 x-Q. Then, for all practical purposes, in this respect they are the same?

A. Yes, in so far as their illuminating properties are concerned.

47 x-Q. What proportion of the lamps manufactured by you are fitted with illuminating conductors made of carbonized paper?

A. One to two per cent., I should judge.

48 x-Q. In preparing your carbons for electric lamps, do you treat them electrically in the presence of hydro-carbon gas?

A. No.

49 x-Q. What training had you had as an electrician?

A. A college course of electricity, the handling of electrical apparatus in the physical laboratory at Princeton, and one year's work at electrical measurements of various kinds at Berlin before entering Mr. Edison's employ; since I have been with Mr. Edison I have made calculations concerning electrical matters, and assisted in a large number of electrical experiments.

50 x-Q. Do you consider yourself an expert in the practical application of electricity in electric lighting.

A. So far as relates to the incandescent electric light, I do.

51 x-Q. Before you went in the employ of Mr. Edison, were you acquainted with him.

A. I had met him once in a visit to his laboratory.

52 x-Q. In answer to question 5 you say when you went into the employ of Mr. Edison he was experimenting with the platinum spiral lamp with a thermal regulator, and was making an extended series of experiments to find the laws of magnetism, and was also studying publications relating to constructions of dynamo machines. How long did Mr. Edison continue on those experiments, and in studying publications referring to constructions of dynamo machines?

A. Up to the present time, I should say; of course with intermissions, giving time for his experiments to be carried out.

53 x-Q. Does Mr. Edison still continue in his experiments upon the platinum spiral lamps with thermal regulators?

A. Yes; through his assistants.

54 x-Q. I read your answer to question 6 of your examination-in-chief (Counsel reads): Please to state when it was that he tested the thread of carbon made in his telephone experiments for the purpose of ascertaining its resistance referred to in the answer I read?

A. My impression is that it was in August or September, 1879, that is the best of my recollection.

55 x-Q. In answer to that question, you say: "I recollect when one of the first successful loops was made; Francis Jehl and I measured the resistance, cold, of the carbon." State, as nearly as you can recollect, when it was that you and Francis Jehl measured the resistance of the paper carbon loop, referred to in that answer?

A. To the best of my recollection, in November, 1879.

56 x-Q. You say, in answer to the same question, that your attention was more particularly drawn to the vacuum pumps, and to the construction of dynamo machines. State, if you please, when it was that you succeeded in getting a pump by which you could obtain a satisfactory vacuum in the illuminating chamber of your lamps?

A. To the best of my recollection, in July, 1879.

57 x-Q. In answer to that same question, you also say: "I remember that we all felt very much elated at the fact of the carbon not changing its resistance, for it showed that there was no wasting away of the carbon; we then felt that it was possible to make a system of electric lighting simply by adding to the life of the lamp which we have since done." State, if you please, in what way you have since added to the life of the lamp?

A. First, by making better clamps for the carbon, so as to hold the carbon firmly, and prevent arcing. Secondly, by making better carbons. Third, by improved methods of getting the vacuum, so as to be sure that all the lamps are well exhausted, even when the workman is not expert.

58 x-Q. In answer to question 11 you say the first recollection you have of Mr. Edison turning his attention to approved means for producing a vacuum in electric lamps was when he sent you to Princeton to borrow a Geissler lamp. Have you been able to fix the date exactly when that was?

A. I have not. I looked last night but could find no record by which I could fix the date exactly.

59 x-Q. Was it after you went to Princeton to borrow the pump, that you came to New York to advertise for a glass-blower for Mr. Edison, as stated in answer to question 12?

A. I did not advertise; but it was after that that Mr. Edison advertised for a competent glass-blower.

60 x-Q. State, if you recollect in what paper it was that that advertisement was inserted?

A. My impression is, the "Herald."

61 x-Q. Give the date as near as you can recollect?

A. It was in the Summer of 1879. I can't fix the date.

62 x-Q. How often did Mr. Edison advertise for glass-blowers, and state whether all the advertisements were subsequent to the time that you borrowed the pump at Princeton?

A. My impression is twice. All the advertisements were subsequent.

63 x-Q. This lamp referred to by you as being at the corner of Mr. Thornall's barn, as burning from fourteen to one thousand five hundred hours—what was the luminosity of that lamp in candle power?

A. I should judge from twelve to sixteen candles.

64 x-Q. How long would such a lamp last, in your judgment, yielding a luminosity of twenty-five candle power?

A. From four hundred to six hundred hours.

65 x-Q. What, in your judgment, would be the average life of the lamps referred to in the record, about which you have been testifying, yielding a luminosity of twenty-five candle power?

A. As the lamps were then made, when not very good, they would arc at high candle power; excepting these, I should say from 100 to 200 hours.

66 x-Q. Do you mean to be understood as saying, if the plan of the lamp was skillfully carried out in its construction and organization, it would endure from one to two hundred hours at a luminosity of twenty-five candle power—referring, of course, to the lamps noted in the record?

A. I do.

66 x-Q. Have you ever tried any of your lamps like Exhibit Edison's Commercial Incandescent Electric Lamp, raised to a luminosity of twenty-five candle power?

A. We never have at that point. We have tried above and below, and my judgment is as stated.

67 x-Q. At what luminosity have you tested the candle power of the lamp referred to in my last question?

A. At forty-eight candles.

68 x-Q. How long did the carbon endure at a luminosity of forty-eight candle power?

A. My impression is somewhere in the neighborhood of fifteen hours.

69 x-Q. What size was the carbon?

A. Substantially the same as that in the Exhibit Edison's Commercial Incandescent Lamp.

70 x-Q. In answer to Question 27 you say that you wrote the article contained in "Scribner's Monthy," for February, 1880, marked Edison Exhibit No. 10; are the statements of facts contained in that article true, of your own knowledge?

A. So far as I was able to verify them they were?

71 x-Q. At the head of that article I find the following statement: "Editor 'Scribner's Monthly.' Dear Sir: I have read the paper by Mr. Francis Upton, and it is the first correct and authoritative account of my invention of the electric light. Yours truly, Thomas A. Edison, Menlo Park, N. Y." Was that written by Mr. Edison?

A. It was at the suggestion of the editors of "Scribner's Monthly." The fac-simile of the letter as written by Mr. Edison is published in the forepart of this book.

72 x-Q. Did Mr. Edison revise this article before it was published?

A. He revised portions of it.

73 x-Q. Did he read the whole of it before it was published?

A. I cannot say. I think he did not read the historical part.

74 x-Q. Which one of the patents granted to Sawyer & Man is "for a stick of carbon rendered incandescent in nitrogen?"

A. In answer to the question I refer to the patent 205,144.

75 x-Q. Now, please to point out the claim in that patent that is "for a stick of carbon rendered incandescentin nitrogen"?

A. Claim 16 is the one that I referred to more especially, which reads: "In the sealed globe of an electric lamp which contains an azotic or other atmosphere, an absorbent of carbonic acid gas," together with the following in the body of the specification, "To charge our lamp we prefer to employ nitrogen gas, and this we produce in the lamp by our improved process in a state of great purity."

76 x-Q. Now, after reading the claim and the extract from the specification, don't you think your statement in your magazine article is too broad?

A. Not in a mere brief summary of the history of electric lighting, as is purported to be given in the article.

77 x-Q. Do you swear that the statement in the magazine article of the Sawyer & Man patent is an accurate statement of the facts as they appear in the patent?

A. The patent itself is the best evidence of what it contains. If what I stated is right it can be verified from the patent.

FRANCIS R. UPTON.

End of Upton's First Interference Deposition.

Upton's Second Interference Deposition.

Pursuant to adjournment the taking of testimony was continued the 18th day of April, 1883.

Present—AMOS BROADNAX, counsel for Sawyer & Man, and GEO. W. DYER, counsel for Edison.

FRANCIS R. UPTON, a witness produced on behalf of Edison, being duly sworn, testifies as follows in answer

to questions proposed by George W. Dyer, counsel for Edison:

1 Q. You have already testified in this case, haven't you?

A. Yes.

2 Q. Do you know Alexander Welsh, who has testified in this case as a witness for Sawyer & Man?

A. Yes.

3 Q. When did you first become acquainted with him?

A. I first met him in the fall of 1880.

4 Q. Under what circumstances?

A. He was employed in the lamp factory, and I came in contact with him in my visits to that place; the Edison lamp factory at Menlo Park was referred to.

5 Q. How long did Welsh work at the lamp factory at Menlo Park?

A. Until about February, 1882.

6 Q. What was his employment when he first worked at the lamp factory?

A. My impression is he was employed in exhausting the lamps.

7 Q. Do you know how long it was after that, he began to work at carbonizing?

A. He commenced carbonizing about February, 1881.

8 Q. Did he commence then to learn the business of carbonizing?

A. He had some slight acquaintance of the methods used from seeing the process carried on. When he commenced at this time he was instructed specially in this branch and gave his whole time to it.

9 Q. Were his instructions confined to Mr. Edison's methods of carbonizing?

A. As far as I know, they were.

10 Q. Was there any time he was given full charge of the carbonizing, and if so, about what time was that?

A. From the time he was employed in carbonizing until he was discharged he was given full charge of the carbonizing.

11 Q. Do you remember the time when he was thus employed in the carbonizing?

A. From February, 1881, till February, 1882, is my recollection.

12 Q. Why was Alexander Welsh discharged?

A. Because we had lost confidence in him.

13 Q. For what reason?

A. When he was placed in charge of the carbonizing it was expressly mentioned that he should report experiments truthfully. We were satisfied he was not doing so; this lack of truthfulness had become a byword in our factory.

14 Q. Since he was discharged what has been his attitude towards the Edison Electric Light Company and the interests of Mr. Edison?

A. Most of the time active opposition.

15 Q. What instances, if any, can you give of active opposition?

A. It has come to my knowledge several times that he was employed in trying to get workmen in the Edison interests, away to other companies.

16 Q. Mr. Welsh, in his testimony, says that you made promises which you failed to fulfill, which led in consequence to a very bad feeling between us; this was an answer to x-Q. 105. Have you anything to say in regard to this statement of Mr. Welsh?

A. I have absolutely no recollection of any unfilled promises to Mr. Welsh. I had no bad feeling towards him, except that I had been provoked by finding out how grossly he had abused the opportunities that were given him.

17 Q. Mr. Welsh says in his re-direct testimony, in answer to questions 116 and 117, that he has since been solicited to return to the employ of Mr. Edison by yourself. Have you anything to say as to that?

A. After his discharge from the lamp factory I was desirous of preventing him from carrying information gained by him at the employ of the lamp factory to opposition companies. I recommended him to the superintendent of the Isolated Company, as a bright

man, at the same time cautioning him regarding his habit of untruthfulness.

18 Q. Do you know Robert White, a witness who has testified in this case in behalf of Sawyer & Man?

A. I do.

19 Q. Did he work at the lamp factory at Menlo Park, and, if so, in what capacity?

A. He worked there as fireman in carbonizing.

20 Q. About what time did he leave the lamp factory, and under what circumstances?

A. He was discharged at the same time as Welsh.

21 Q. Why was he discharged?

A. Because we did not think it prudent to discharge Welsh and leave his intimate friend behind.

22 Q. Mr. Welsh testifies that he made certain exhibits of paper carbon on a morning in July, 1881, between about 7:15 and a quarter to eight, and that it was necessary to complete them at that hour because the train left at eight (8) for New York, and Robert White testifies that you were present during a portion of the time when such exhibits were being made. What recollection have you as to the facts thus testified about?

A. I have no distinct recollection of being present at the time mentioned. I am very positive that there was no train at eight for New York.

24 Q. What hour nearest that time did the train run?

A. At 7:30, within a very few minutes; the next train after was 9:20.

24 Q. Robert White testifies that in that carbonization you threw water upon the carbonizing box to hasten the cooling of it. What do you say to that statement?

A. I do not recollect doing anything of the kind.

25 Q. He testified further that you then carried away the specimens of carbonized paper for the purposes, Mr. Welsh informed him, of giving them to Mr. Chas. Batchelor at the depot. What have you to say to that statement?

A. I can't recollect so doing.

26 Q. Do you remember the fact that at the time

Mr. Batchelor testified in this case, in July, 1881, he produced specimens of carbonized paper purporting to have been made in the manner described by Mr. Man and Mr. Sawyer in their previous testimony in this case?

A. I have been informed that he did so.

27 Q. Have you any knowledge or information who made those exhibits produced by Mr. Batchelor, and where they were made, and during what time of the day?

A. I have always understood that he (Mr. Batchelor) made them himself, assisted by Mr. Atcheson, the night before he testified regarding them, and that they were made in the laboratory at Menlo Park.

28 Q. Was the laboratory a distinct building from the lamp factory, and, if so, about what distance from it?

A. It was entirely distinct and separated from the lamp factory by a distance of about 1,500 feet. The lamp factory was at the foot of the hill, the laboratory on top. Men employed in one were not allowed in the other, except on business.

29 Q. Were you present during the time when Mr. Alexander Welsh gave his evidence in this case?

A. I was most of the time.

30 Q. Were you present when Alexander Welsh produced and put in evidence samples of carbonized paper purporting to have been made in accordance with descriptions in the former testimony of Mr. Man and Mr. Sawyer?

A. I was.

31 Q. Did you examine such specimens at the time sufficiently to form an opinion upon them?

A. I did.

32 Q. What opinion did you then form of them, as adapted to practical use, in incandescent electric lamps?

A. I formed a very decided opinion that for practical use in incandescent electric lamps they would prove an utter failure. First, in manufacturing lamps the breakage in clamping such loops would be so great as to preclude their use in competition with materials now ordinarily used. Secondly, owing to the irregularity of the carbon they, if it were possible to bring them to incandescence, would be so irregular as to shorten their life very materially. Third, owing to their extreme lack of elasticity it would be almost impossible to transport lamps if such could be made.

33 Q. In the first reason given in the previous answer what would cause the breakage in clamping referred to in that answer?

A. In clamping carbons it is necessary to handle them and to hold them firmly. From my experience I should judge there would be great liability of breakage in either of these operations. The cause of it would be the friable nature of the carbon. I scarcely dared touch the exhibits for fear of breaking them.

Francis R. Upton.

End of Upton's Second Interference Deposition.

GARDEN'S McKEESPORT DEPOSITION.

New York, March 12, 1889.

Met pursuant to adjournment.

Hugh R. Garden, being duly sworn, says:

1 Q. What is your name, age, residence and occupation?

A. Hugh R. Garden; age, 48; occupation, lawyer; residence, New York City.

2 Q. Do you know of a corporation known as the Electro-Dynamic Light Co., and if so, how, if at all, are you connected with it?

A. I know the corporation styled the Electro-Dynamic Light Co., and am the president of it.

3 Q. How long have you been president of said corporation?

A. I was elected the president of said corporation during January, 1889, I think.

4 Q. Has the Electro-Dynamic Light Co. a secretary, and if so, please give his name and residence?

A. It has a secretary; his name is C. W. Stocker; his office address is room 607-608, at No. 32 Nassau street, N. Y.

5 Q. Have you now in your possession the book of minutes containing the record of the proceedings of the Board of Trustees of the Electro-Dynamic Light Co.?

A. I have in my possession a book purporting to contain such record.

6 Q. During what years does said minute book contain a record of the proceedings of the Board of Trustees of the Electro-Dynamic Light Co.?

> Counsel for the complainant stated of record, that in accordance with the request of Mr. Lowrey, of counsel for defendant, he has requested the witness to produce the said minute book of the Electro-Dynamic Light Company, before the Examiner this morning, and that the witness has done so in accordance with said request, and the book is now produced for use of the defendant's counsel, and the question is objected to for the reason that the book itself is the best evidence and of the periods covered by said book.

A. I am not familiar with the dates or the contents of the minute book, having had no connection officially, with the Electro-Dynamic Light Co. prior to the winter of 1888-1889, but at the request of counsel I have brought the minute book, and I offer the same in evidence.

> Defendant's counsel objects to that part of the answer of the witness wherein he states that he offers the minute book in evidence as not responsive to the question, and he does not consent that the same be offered in evidence at this stage of the examination of the witness.
>
> Counsel for complainants requests that the fact be stated that the witness has shown the book to counsel (a book is handed to defendant's counsel by the witness. J. H. K., Ex.).

7 Q. Will you now produce the minute book of the Board of Trustees of the Electro-Dynamic Light Co., and allow the defendant's counsel to inspect the same?

A. Defendant's counsel has now the minute book in his possession, and the witness will be pleased to have him examine it thoroughly.

> It is conceded by complainants' counsel that the book produced is the minute book of the Electro-Dynamic Light Company, and the only one they ever had. As to the period covered, counsel states that the book itself is the best evidence of that. As to the record of proceedings, counsel also concedes that it contains a correct statement of the proceedings of the Electro-Dynamic Light Company during the period embraced in the book.

8 Q. Please examine said minute book at pages 46 to 53 inclusive, and state whether you find therein a record of the proceedings of a meeting of the Board of Trustees of the Electro-Dynamic Light Company purporting to have been held on the 20th day of March, 1879?

> Objected to as the witness has no personal knowledge of said meeting, and the book itself is the best evidence of the fact inquired for by the counsel, and of its own contents.

A. I can only onswer the question by reading what appears on the pages 46-53 inclusive, in the book referred to. After reading from the minute book, I now state that within the pages referred to there is what purports to be a record of the proceedings of Board of Trustees of the Electro-Dynamic Light Company, held on the 20th day of March, 1879.

Defendants' counsel offers in evidence from the book of minutes of the Electro-Dynamic Light Company a record of the proceedings of the Board of Trustees of said company, purporting to have been held on the 20th day of March, 1879, at 3:30 P. M., No. 3 Nassau street, New York City. Said record being on pages 46, 47, 48, 49, 50, 51, 52 and 53, inclusive, of said minute book, and purporting to have been signed by W. E. Sawyer, secretary. Said record of March 20th, 1879, is filed in evidence and marked Defendants' Exhibit "Electro-Dynamic Light Record, March 20th, 1879."

The offer is objected to as incompetent, unless the whole book is offered in evidence, that being a part of their record and showing only a portion of the proceedings of the said company appertaining to the subject included in the offer, and as an attempt on the part of the defendant to cut off the complainant from proper cross-examination, and also to conceal from the Court matter material to the controversy. Notice is hereby given that a motion will be made at or before the hearing of this cause upon proper notice as to time and place to strike out the mutilated record thus attempted to be offered by the defendant.

9 Q. Please examine said record Defendants' Exhibit "Electro-Dynamic Light Record, March 20th, 1879," and state if you know in whose handwriting it is?

A. I have examined the record referred to and I do not know in whose handwriting it is.

10 Q. Please state from whom you received said book of minutes and how long it has been in your possession?

A. The minute book was brought to my office at the time that I was elected president of the company. But who brought it there I do not know. I think this was in January, 1889. I see by reference to the minute book itself that I was elected president on the 19th of December, 1888, to fill the unexpired term of Mr. Thomas Wallace, the former president, and that at the annual election which took place in January, 1889, I was re-elected president, and the book was probably brought to my office at the time I was elected in December, 1888, and has since been in my custody.

11 Q. At the time said minute book was delivered to you, was it put into your custody as the minute book of the Electro-Dynamic Light Company in which the proceedings of its Board of Trustees were recorded?

A. I so understood it.

Adjourned to 2 P. M.

March 12, 1889.

Met pursuant to adjournment.

Counsel present as before.

It is hereby stipulated that a copy of the minutes of the Board of Trustees of the Electro-Dynamic Light Company of the meeting held March 20th, 1879, offered in evidence by the counsel for the defendant, may be copied in the record by the Examiner and have the same force and effect as the original in the minute book of the said company, subject, however, to the objection made by counsel for the complainant.

It is also agreed that the complainant will produce the said minute book at the hearing of this cause, or at any time during the taking of the defendant's evidence on proper notice from the defendant.

The Examiner here copies the said minute.

At an adjourned meeting of the Board of Trustees of the Electro-Dynamic Light Co., held at No. 3 Nassau street, on Thursday, March 20th, 1879, at 3.30 P. M. Present—Messrs. Albon Man, Hugh McCulloch, Wm. H. Hays, Jacob Hays, Lawrence Myers, Jas. P. Kernochan and W. E. Sawyer; the president in the chair.

The minutes of the previous meeting and of the two adjournments which followed were read and approved.

The treasurer's report to date was presented and read, showing a balance of cash in bank of $2.61. Total liabilities, $3,536.72; of which amount there is due to

Albon Man	$1,850
Jacob Hays	750
Hugh McCullough	150
Lawrence Myers	150
Wm. H. Hays	150
J. P. Kernochan	150
Man & Parsons, lawyers	310 50

From which the president promised to secure a reduction.

On motion the report of the treasurer was referred to the Auditing Committee, consisting of the president, vice-president and Secretary, for examination and approval.

The president then made the following report which the secretary took down *verbatim*:

"The president reports that on Tuesday last he discharged the workmen employed by the company at No. 94 Walker street, and gave them notice that nothing further would be required of them by the company, that he consented to Mr. W. E. Sawyer doing any work he desired to do there; and that since that time Mr. Sawyer has been at work there. There is nobody left in the employ of the company except Mr. Edwin L. Myers. The men are paid up to the expiration of the time when they were discharged. Edwin L. Myers was put in charge of the shop by the president to look after the property of the company, and remains in that capacity there, receiving a salary of $12 per week. Mr. Sawyer has expressed to the president of the company the greatest possible confidence that the principle upon which he had been at work to build lamps was correct, and that those lamps that had been put up, except for some unknown reason (probably something about the filling), would be permanent and last forever. Some half a dozen or more lamps that are there are perfect and he (Sawyer) believed would never burn out, but remain as they are. but, in his (Sawyer's) judgment, a manufacture of lamps of that character was so uncertain that he declined to put them on exhibition anywhere. Since the last meeting of the company Mr. Sawyer has been at work principallly upon a feeder lamp. On Tuesday evening of this week the feeder lamp was completed and was filled with illuminating gas and lighted up; fed up from the outside without any connection with the air at all, but fed up from the outside. The lamp was filled with illuminating gas because the conveniences of obtaining nitrogen were not at hand, and then a vacuum made in the lamp, taking out most of the gas and leaving only a very small portion in. The lamp burned well for about half an hour in illuminating gas and was then shut off. Mr. Sawyer had it taken down on the next day which was Wednesdap, and filled by Mr. Stillman, and this morning Mr. Edwin L. Myers run it and fed up the carbon pencil twenty-one times, and his report is that there was no consumption of it, and that the lamp seemed to be a good and perfect lamp; that the carbon was entirely defective and good for nothing, because it had not been treated. It should have been treated before it was put in the lamp. Mr. Sawyer expresses confidence that lamps put up with a feeder of that kind will last forever, and he will be ready to put it on exhibition, but the president himself expresses his own views in regard to it that, while Sawyer's views are probably correct, personally, for other reasons, he is unwilling to go on expending money of himself and others in building lamps."

On motion, it was ordered that the report of the president be entered on the minutes and his action approved.

The secretary, Mr. Sawyer, then proposed, that the gentlemen present, being unwilling to go on with the business of the company, that he should be allowed the free use of the shop and tools of the company until the 20th of April, in and with which to conduct his own experiments at his own expense; that he should be allowed three months' time in which to pay the debts of the company, and that upon his paying the debts of the company, not to exceed four thousand dollars in amount, all of the members of the board now present, excepting himself, shall turn into the treasury of the company two-thirds of the stock and scrip originally held by them, which shall be used as a working capital to secure funds for carrying on the business of the company, the same to be sold at no less than fifty cents on the dollar of par value. The proposition of the secretary was considered and accepted by unanimous informal agreement, with the understanding that the remaining one-third of stock and scrip retained by the present members of the board, excepting himself, shall be protected from assessment or debt either by two of the present board members, excepting the secretary, retaining their board membership in any new organizations to be effected, or by some other means to be devised hereafter.

On motion of Mr. McCulloch, it was

Resolved, That all authority heretofore given, expressly or by implication, to any officer of this corporation to contract debts for the company, be and hereby is rescinded.

Resolved, That all expenses of the company, excepting the salary of Mr. Edwin L. Myers, be revoked, and that he shall be continued in charge of the property of the company, at No. 94 Walker street, until otherwise ordered.

Resolved, That W. E. Sawyer be authorized to use, for experimental purposes, at his own expense, the office and premises, machinery and tools of the company, at No. 94 Walker street, free of rent until the 20th of April next.

The secretary was requested to state in the minutes that the feeder lamp invention made by him at the expense of the company is the property of the company for the United States, to which he hereby agrees and assents, and will make all necessary assignments, provided the company procures the patent upon it within a reasonable time.

Adjourned.

W. E. Sawyer, Secretary.

Cross-examination:

12 Q. Please examine the minute book and state whether there are any minutes of any other meeting of the trustees of the Electro-Dynamic Light Company, signed by "W. E. Sawyer, Secretary," and in the same handwriting as the minute of March 20th, 1879, and if so, please give the dates of said meetings?

> Defendants' counsel objects to the question as incompetent, on the ground that the question calls for evidence not responsive to the examination-in-chief, and because it calls for the opinion of the witness as to the handwriting of W. E. Sawyer, and the witness is not shown to be competent to express an opinion upon the subject inquired about or to make a comparison as to the similarity or dissimilarity of the handwriting of the person who recorded the proceedings in said book of minutes.

A. Beginning at page 1 of said book I find what purports to be a meeting of the trustees of the Electro-Dynamic Company, held at No. 3 Nassau street on the 15th day of July, 1878, the said record ending on the 15th page of said book. The record of the proceedings, or alleged proceedings is in the same handwriting as that of the proceedings of March 20th, 1879, and it closes on page 15 with the words "W. E. Sawyer, Secretary."

The same remarks apply to a record of a meeting purporting to have been held September 10th, 1878, at the same place, beginning on page 16 and ending on page 18.

The same remarks apply to a meeing of the Board of Trustees purporting to have been held October 8th, 1878, beginning on page 19 and ending on page 20, except that the word "Secretary" is not written out in full, but is written "Secy."

The same remarks as the last apply to a meeting of said Board purporting to have been held October 15th, 1878, beginning and ending on page 21.

The same remarks apply to a record of what purports to be a meeting of said Board held October 31st, 1878, beginning on page 22 and ending on page 26.

The same remarks apply to a record of what purports to be a meeting of said Board held on the 12th of November, 1878, beginning at page 27 and ending at page 36.

The same remarks apply to a record of what purports to be a meeting of said Board on December 12, 1878, beginning on page 37 and ending on page 40.

The same remarks apply to what purports to be a record of a meeting of said Board January 14, 1879, beginning and ending on page 41.

The same remarks apply to a record of what purports to be a meeting of said Board February 18, 1879, beginning and ending on page 42.

The same remarks apply to what purports to be a meeting of said Board held February 25, 1879, beginning on page 43 and ending on page 45.

On page 45 there is also a record of what purports to be a meeting held March 11, 1879, which is not in the same handwriting, except that the signature "W. E. Sawyer, Secy.," is in the same handwriting as that referred to in the question asked.

There is also on page 45 a record of what purports

to be a meeting held March 18th, 1879, which is altogether, including the signature, in the handwriting referred to in the question.

The same remarks apply to what purports to be a record of a meeting of said Board held April 8th, 1879, beginning on page 54 and ending on page 55.

The same remarks apply to what purports to be a meeting of said Board held April 19th, 1879, beginning and ending on page 56.

The same remarks apply to what purports to be a meeting of said Board held April 26th, 1879, beginning on page 57 and ending on page 64.

The same remarks apply to what purports to be a record of the proceedings of said Board held May 13, 1879, beginning at page 65 and ending at page 66.

The same remarks apply to what purports to be a record of a meeting of said Board held May 14, 1879, beginning and ending on page 67.

The same remarks apply to a record of what purports to be a meeting of said Board held May 20th, 1879, beginning on page 68 and ending on page 76.

The same remarks apply to a record of what purports to be a meeting of said Board held June 10th, 1879, beginning on page 77 and ending near the top of page 78.

I find nothing more in said book in the handwriting referred to.

Same objection to answer as to the question.

13 Q. State whether the minutes you have referred to of meetings beginning on July 15th, 1878, and ending on June 10th, 1879, constitute, together with the minutes of March 20th, 1879, all the minutes contained in said minute book between those dates?

Same objection as to last question; also as immaterial and irrelevant, and as improper and incompetent, because the minute book is the best evidence of what it contains.

A. They constitute all of the minutes recorded in said book between the dates mentioned.

14 Q. Please read to the Examiner the minutes of each meeting you have referred to in your 12th answer, so that he may take them down in the record?

Defendant's counsel objects to the question and to the evidence called for thereby upon the ground that the same is immaterial and irrelevant and the question calls for new matter not relating to or growing out of the examination-in-chief, and because the original record itself, if competent at all, is the only competent evidence of the facts therein recited, and defendant's counsel further objects and protests that it is not competent or proper for the complainants to burden the record of the defendant with new and irrelevant matter or to take the defendant's time, which is limited, in spreading their own evidence upon defendant's record, thereby consuming defendant's time and greatly adding to the expense of this litigation.

The defendant's counsel also objects that no proper or sufficient foundation has been laid by the complainant's counsel for the introduction of the minutes of said alleged meetings in evidence.

The defendant gives notice that if the complainant's counsel pursues the line of examination indicated in the question, he will make said witness his own and will be bound by the evidence called out, and he further gives notice that he will move the Court before final hearing or at final hearing to strike said incompetent, immaterial and irrelevant matter from defendant's record.

Counsel for complainant states that he has no desire to take defendant's time; that he has proposed to defendant's counsel to permit the Examiner's clerk, who is taking this testimony, to copy the minutes called for in the question on the record and to permit the witness to compare the said copy after it is made. That during said time, the examination of other witnesses can proceed, attendance of counsel being unnecessary here, but defendant's counsel has seen fit to refuse. Complainant's counsel offers to have copies of the said minutes made and put in subject to the objection of defendants' counsel already taken, just as complainant's counsel has stipulated in a copy of the one minute defendants' counsel has offered. Complainant's counsel states that so far from delaying defendants he has provided counsel to attend two other examinations now going on in defendants' behalf in different places, and that his course in this matter has rendered necessary by the unfair and improper course of the defendant in attempting to put in part of the minutes in the hand of William E. Sawyer, without putting the whole of them in.

A. (Witness reads):

"At a meeting of the Trustees of the Electro-Dynamic Light Co. held at No. 3 Nassau St., in the City of New York, on the 15th day of July, 1878.

Present—Messrs. Hugh McCulloch, Wm. H. Hays, Albon Man, Jacob Hays, Lawrence Myers and W. E. Sawyer; Mr. Jas. P. Kernochan being represented by Mr. Albon Man, Trustees.

On motions Mr. Hugh McCulloch was appointed chairman, and W. E. Sawyer, secretary, *pro tem.*

The counsel of the company reported that the certificate of incorporation had been filed in the office of the Secretary of State and in the office of the Clerk of New York County, on the 11th day of July, 1878; and presented a certified copy of the certificate as filed.

On motion of Mr. Albon Man it was resolved to ballot for officers.

The ballot resulted in the unanimous election of the following officers:

President, Wm. H. Hays.

Vice-President, Albon Man.
Secretary, W. E. Sawyer.
Treasurer, Jacob Hays.

The Vice-President elect took the chair and on motion it was

Resolved, That the patents and patent rights and agreements belonging to William E. Sawyer and Albon Man, relating to the subject of electric lighting and the production and distribution of electric currents be purchased by the company and that the President and Secretary be and hereby are directed to issue to the said Sawyer and Man the whole capital stock of the company and two hundred and ninety thousand dollars in scrip certificates of the company, payable out of profits, in the form now presented to the company and exhibited here on the minutes; the price at which said patents and patent rights and agreements are purchased being $300,000.

Following is a list of the patents, viz.:
"Electric Lamps," No. 205,144.
"Electric Lighting System," No. 205,303.
"Regulators for Electric Lights," No.205,305.

And two-fifths of the following patents, viz.:
"Electric Engineering and Lighting Apparatus and System," No. 194,111.
"Electric Engineering and Lighting System," No. 196,834.
"Electric Lighting Apparatus," No. 194,503.
"Electric Candles," No. 194,500.

The agreements between W. E. Sawyer and Albon Man bear date as follows:
February 15th, 1878.
March 19th, 1878.
March 25th, 1878, and
May 11th, 1878.

On motion the Secretaty read the following By-laws, which were adopted, viz.:

BY-LAWS
OF
THE ELECTRO-DYNAMIC LIGHT COMPANY.

I. Board of Trustees.

The stock, property and concerns of the company shall be managed, except as hereinafter provided, by a board of seven Trustees, who shall be stockholders, and shall hold their offices until others are elected in their stead, and who shall have power to fill vacancies in their body, but only by the concurring vote of a majority of the Trustees then existing.

II. Officers.

The regular officers of the company shall be a President and Vice-President, Treasurer and Secretary.

III. Annual Election.

The annual election of Trustees shall be held on second Tuesday of January in each year, at the office of the company in the City of New York, at such hour as the board shall direct, or, if no other hour be designated, then at 3 o'clock P. M. At the same time and place three inspectors shall be chosen to hold the next annual election. Such election shall be by ballot; each share of stock entitling the holder to one vote.

IV. Election of Officers.

The President, Vice-President, Treasurer and Secretary shall be elected annually within forty days after the election of the Board of Trustees, and they shall hold their offices until their successors are chosen, save in cases of removal by the board or other disqualification.

Vacancies in office may be filled at any meeting of the board.

Such elections shall be by ballot; and a majority of the whole board for the time being shall be necessary to a choice.

V. Meetings of the Board.

The stated meetings of the Board of Trustees shall be held on the second Tuesday of each month, at the office of the company in the City of New York, at such hour as the board shall direct; or, if no other hour be designated, then at 3 o'clock P. M.

A majority of the whole number of Trustees for the time being shall constitute a quorum for the transaction of business at any meeting, whether stated or special.

The President, Vice-President or any two Trustees may direct the call of a special meeting of the board at discretion.

Any meeting may adjourn from time to time to a day and hour then specified.

VI. Call of Special Meetings.

Special meetings may be called by the President, Vice President or any two Trustees, notice to attend which shall be given to all by mail or otherwise.

VII. Order of Business.

The order of business at meetings of the Board of Trustees (unless dispensed with at any meeting by unanimous vote) shall be:

1. Calling the roll.
2. Reading the minutes of the preceding meeting or meetings.
3. Reading the minutes and reports, consecutively, of the Executive Committee, President, Treasurer standing committees and special committees.
4. Miscellaneous business.

All questions shall be decided by the vote of a majority of the Trustees present at any meeting, except as herein otherwise provided; and the yeas and nays shall be recorded on the demand of any member.

VIII. Executive Committee.

There shall be an Executive Committee to consist of three Trustees. It shall be chosen, and vacancies therein filled, by the Board of Trustees. The Committee may fix the time for its stated meetings, and may be called together also for special business by any member thereof.

All ordinary executive powers, not specially delegated to the officers of the Company, or to other Committees, shall be exercised by the Executive Committee, subject, however, to such regulations or directions as the Board of Trustees may adopt.

The Executive Committee shall have power, subject to such regulations as the Board of Trustees may adopt, to suspend any superintendent, clerk or agent of the company from duty or employment. It shall also exercise a general supervision over the pecuniary affairs of the company, and advise with the officers in respect to any measure of finance, and examine as often as they may think proper, or as the Board may direct, all accounts and vouchers of the Treasurer and other officers or agents, and report thereon.

IX. Subordinate Officers.

The Board of Trustees may appoint such superintendents and other subordinate officers, clerks or agents as the business of the Company may require, and may fix their salaries or other compensation.

X. Duties of President.

The President shall preside at the meetings of the board and discharge all duties usually pertaining to the office.

In case of his absence or disability, his duties shall be performed by the Vice-President; and if both be absent or unable to attend to such duties, then a president *pro tem.*, to be named *viva voce* or otherwise by the board.

XI. Duties of Treasurer.

It shall be the duty of the Treasurer to receive and safely keep all moneys belonging to the company, which shall from time to time be deposited in bank to the credit of the company by its corporate name. He shall keep correct books of account, which shall be the property of the company; and shall preserve correct vouchers for all disbursements, except petty cash; and shall exhibit the financial condition of the company by report at the annual meeting, and also, whenever required, to the Board of Trustees or Executive Committee. He shall be custodian of the corporate seal.

XII. Duties of Secretary.

It shall be the duty of the Secretary to attend the meetings of the board and keep correct and full minutes of the proceedings; to keep the records, correspondence, and papers of the company; to give notice of all special meetings of the company and of the Board of Trustees, and also (when requested) of the meeting of committees; to furnish to each committee or its chairman a copy of every resolution appointing such committee, or relating to the committee or its business; to conduct the general correspondence of the company; and to discharge all other duties usually devolved upon a Secretary.

XIII. Transfers of Stock.

The Secretary shall keep a suitable (or scrip)* book in which all transfers of the stock shall be made.

*Interlineation in book.

No transfer of stock or scrip shall be made until the previous certificate (if any) given for the same stock or scrip shall have been surrendered and canceled.

No transfer shall entitle the holder to a dividend, or to vote upon stock or scrip, unless regularly entered upon the transfer book.

The transfer book shall be closed for ten days prior to the annual election and for ten days prior to the payment of any dividend.

On the day of the annual election the Secretary shall furnish for use of the inspectors an alphabetical list of all the stock and scripholders at the time of closing the books preparatory thereto, with the number of shares held by each.

XIV. Stock Certificates.

All certificates of stock and scrip shall be signed by the President and countersigned by the Secretary, and the corporate seal affixed, and, unless so authenticated, they shall not be valid.

XV. Safeguard against Personal Liability.

For the protection of the stock and scripholders and officers of the company against personal liability, and to preserve the credit of the company, it is expressly provided that no work shall be ordered or authorized, or liability of any kind incurred by or on behalf of the company unless ample means shall at the time be in the treasury and immediately available to meet such liability. It shall be the duty of the Executive Committee to see that this by-law is strictly complied with, and they shall have full power to prevent any violation of it by officers or agents of the company.

XVI. Special Meetings of Stock and Scripholders.

Special meetings of the stock and scripholders shall be called by the Secretary when required to do so by the President or Board of Trustees, or by stock and scripholders owning at least one-half in amount of all the capital stock and scrip. Such call shall be made by circular addressed by mail to all the stock and scripholders, whose residence shall be known, to their residence or at their registered address.

XVII. Disbursing Officers may be Required to give Security.

The Treasurer, or any other officer or agent of the company who shall control or disburse the moneys thereof, shall (if the Board of Trustees or Executive Committee require the same) give security for the faithful discharge of the duties of such office or agency, and to account for such moneys, which security shall be in such form and amount as said board or committee may require.

XVIII. Corporate Seal.

The corporate seal of the company shall be a circular one with the name of the company thereon, and the word "seal," the impression of which is affixed to the record of these by-laws in the minute book of the company.

Impression of Seal.

XIX. Execution of Documents.

All deeds, leases and other documents affecting the property of the company, and requiring to be executed under its seal, shall be executed by the President or acting President and attested by the Secretary.

XX. Checks.

No moneys can be drawn from bank or other place of deposit thereof except by checks signed by the President or Vice-President and also by the Treasurer.

XXI. Alteration of By-laws.

These by-laws may be altered or amended by a vote of not less than two-thirds of the whole number of trustees for the time being at any regular meeting of the board, provided distinct notice of the intention to propose such alteration or amendment shall have been given in the notice calling such meeting, or at the next previous regular meeting when a quorum shall have been present.

The Secretary presented a seal, impression of which is on the margin of the minutes, which on motion was adopted as the seal of the company.

On motion, Messrs. Lawrence Myers and Jacob Hays were appointed a committee to supervise and receive the assignments of patents and agreements and to supervise the issue of the stock and scrip of the company in accordance with the resolution adopted.

The Committee reported that they had received the assignments of the patents and agreements referred to in the resolution and presented the same to the Trustees.

On motion, Messrs. Classon & Hays, of No. 3 Nassau St., New York City, were appointed transfer agents of the Company.

Messrs. Wm. H. Hays and Albon Man tendered their resignation of the offices to which they had been elected, and the resignations were accepted, whereupon,

On motion, it was resolved to proceed to ballot to fill the vacancies thus created.

The balloting resulted in the unanimous election of Mr. Albon Man for President, and Mr. Lawrence Myers for Vice-President.

Adjourned subject to call.

W. E. Sawyer, Secretary.

Pursuant to call the regular monthly meeting of the Board of Trustees of the Electro-Dynamic Light Co. was held at No. 3 Nassau St., on Tuesday, Sept. 10th, 1878. Present: Messrs. Hugh McCulloch, Wm. H. Hays, Jacob Hays, Lawrence Myers, Albon Man and W. E. Sawyer. The minutes of the previous meeting were read and approved.

The President reported that an informal proposition had been made to him to purchase ten thousand dollars ($10,000) of the scrip of the Company which has been set apart as a working capital and stands in the name of Jacob Hays, Treasurer, in trust, at the par value thereof; whereupon,

On motion of Mr. McCulloch, the President and Treasurer were authorized, by a unanimous vote, to sell and transfer ten thousand dollars of the scrip held by the Treasurer in trust.

The President further reported that he had expended of his own money and taken vouchers in the name of the Company therefor receipted as paid by him to the extent of $729.74 in the preparation of lamps and other electrical apparatus and in the payment of $250 to W. E. Sawyer for $1,000 of the scrip of the Company, assigned to the Company by Mr. Sawyer; and that there is a small bill in addition due to Messrs. Arnoux & Hockhauser, Nos. 2 and 4 Howard St., New York, for work and materials.

On motion it was resolved that the Vice-President and Treasurer be authorized to act as an Auditing Committee to audit the accounts when there is money in the treasury to pay the same.

The President further reported that there is a proposition pending for the privilege of placing the lighting apparatus of the Company in the Davol Mills at Fall River, Mass.

On motion of Mr. Wm. H. Hays the President was authorized in his discretion to make arrangements with the proprietor of the Davol Mills.

The President further reported that the Company is in need of a dynamo-electric machine for the proper exhibition of its lighting apparatus, the price of which

is $600, whereupon, on motion of Mr. McCulloch, it was

Resolved, That the President be authorized to order such a dynamo-electric machine as may be needed.

On motion it was resolved that the President be authorized to employ as chemist of the company Prof. F. N. Holbrook, of Columbia College.

On motion it was resolved that the clerk of Mr. Jacob Hays be employed to take care of the books of the company, and to be paid a fair price for his time and services.

Adjourned.

W. E. Sawyer,
Secretary."

At the regular monthly meeting of the Board of Trustees of the Electro-Dynamic Light Co., held at No. 3 Nassau St., on Tuesday, Oct. 8th, 1878. Present—Messrs. Wm. H. Hays, Jacob Hays, Lawrence Myers, Albon Man and W. E. Sawyer.

The minutes of the previous meeting were read and approved.

The President reported:

1st. That he had made arrangements with Mr. Wm. C. Davol, Jr., Treasurer of the Davol Mills of Fall River, Mass. (at the expense of the Mill Co.),* to equip the said mills, at the expense of the Mill Co., with the electric lighting apparatus of the Electro-Dynamic Light Co., the Mill Co. to pay a royalty of one hundred dollars per annum for the use of the same and as an acknowledgment of the patents and rights of this company.

2d. That the apparatus of the company is substantially complete for exhibition.

* Erased in book.

3d. That the present workshop of the company is unsuitable for the exhibition of the light and experimental purposes.

On motion of Mr. Jacob Hays, it was resolved :

That the President and Treasurer be, and hereby is, authorized to procure suitable quarters for manufacturing and exhibiting the apparatus of the company.

On motion it was resolved :

That the President and Treasurer be, and hereby are, authorized to pay W. E. Sawyer at the rate of fifty dollars per week as electrician of the company.

On motion of Mr. Wm. H. Hays, the President was authorized to procure Letters Pattent of the United States upon new inventions as speedly as he may deem it necessary.

On motion, the President was authorized to employ Mr. E. L. Myers as chemist of the company in place of Prof. Holbrook.

Adjourned.

W. E. Sawyer,
Sec'y.

At a special meeting of the Board of Trustees of the Electro-Dynamic Light Co., held at No. 3 Nassau St., on Tuesday, Oct. 15th, 1878, notice to attend which was sent to all. Present—Messrs. Hugh McCulloch, Wm. H. Hays, Jacob Hays and Lawrence Myers. The President being absent, Mr. Myers, Vice-President, was called to the chair. Mr. Jacob Hays acted as Secretary *pro tem.*

On motion of Mr. Wm. H. Hays, the President was authorized to exhibit the electric light wherever he may deem proper for the interests of the company.

On motion of Mr. McCulloch, the President was authorized to procure letters patent in foreign countries upon the inventions owned by the company, provided the expense of procuring such letters patent can be paid by sale of stock of the company.

Adjourned.

W. E. Sawyer, Sec'y.

At a special meeting of the Stockholders of the Electro-Dynamic Light Co., held at No. 3 Nassau St., on Thursday, Oct. 31st, 1878, notice to attend which was sent to all. Present—Messrs. William H. Hays and Jacob Hays, Hugh McCulloch, Lawrence Myers, Jas. P. Kernochan, Albon Man, W. E. Sawyer, Wm. H. Church and H. L. Judd, the President in the chair, the Secretary read the following communication from Mr. G. P. Lowrey :

Porter, Lowrey, Soren & Stone,
Attorneys and Counsellors at Law,
No. 3 Broad Street, (Drexel Building),

New York, Oct. 30th, 187 .

P. O. Box 1836.

Dear Sir—Referring to my visit to 94 Walker St., this morning, I think it desirable to repeat to you more deliberately than may be done in a hurried conversation, that the field of electric lighting is so vast and promises such great results, that good business men would commit a great error if they should allow themselves to become, in the outset, involved in any uncalled for struggle for the possession of the whole field, and a small part of it would be enough for all.

As I said to you this morning, the suggestions which passed between us, arising apparently in both our minds out of the same practical considerations, were not intended by me to express the opinion of my associates, for I had not seen any of them since reading in the morning paper the announcement of the Sawyer & Man Light; nor do I understand what you said as in any way committing you, except to the general proposition, that it was always in these mttters wiser to unite strong parties than to divide them and leave them to expend their strength in opposition.

I want to repeat, therefore, that I shall be at all times in favor of considering more carefully the general ideas which we mutually expressed, and that without any very great reference to the question who would or who would not succeed in the final contest.

As I understand it, you have not a correct idea of Mr. Edison's light ; in fact, he has not allowed any one to know what his invention consists of, but I understand that you have what is apparently to me a very good light, and even if we were able to sustain both rival patents, we should be competitors, which itself would be commercially a great mistake.

I have already described to one of the Directors of our Company what I saw of your light, and I shall mention our conversation to others as I shall chance to meet them.

You will be glad to hear that a telegram from Menlo Park this morning informed me that Mr. Edison slept twelve hours last night without pain, and is therefore out of the difficulty which has prevented him from working for the last few days.

I presume that your foreign patents are taken out and I think there is a much greater field over there than here, and also if there should be a practical union of these interests in any way it would be enormously to the advantage of both, on the other side, to be represented by the same strong banking house or houses.

Very truly yours,
(Signed), G. P. Lowrey.

Albon Man, Esq., 94 Walker Street, City.

On motion, Messrs. Hugh McCulloch, Wm. H. Hays and the President of the Company were appointed a committee to confer with Mr. Lowrey in relation to the subject matter of the foregoing communication.

Adjourned.

W. E. Sawyer, Sec'y.

At the regular monthly meeting of the Board of Trustees of the Electric-Dynamic Light Co., held at No. 94 Walker street, on Tuesday, November 12th, 1878, at 4 o'clock P. M.

Present—Messrs. Albon Man, Jacob Hays, Lawrence Myers and W. E. Sawyer.

The reading of the minutes of the previous meeting was dispensed with.

The President reported that he had received two more letters from Mr. G. P. Lowrey, which the Secretary read as follows :

New York, Nov. 2d, 1878.

Dear Sir : I have this moment received your letter, which, however, I have not time to read as I am going out.

I was surprised this morning to hear that my letter to you was being spoken of as an advance towards a consolidation of our company with yours. I am sure you cannot have made such a mistake. At any rate, if such an impression was derived from what I wrote, there was no such specific purpose in my mind, and I desire to correct it now and to add that I have not the slightest idea that the Edison Electric Light Company would entertain any such proposition from you, and certainly they would not make it.

It is one of the dangers of private intercourse that it is liable to these misconstructions.

Very truly,
G. P. Lowrey,
By K.

Albon Man, Esq.,
94 Walker St.

New York, Nov. 6th, 1878.

Dear Sir : I received your letter of Oct. 31st just as I was leaving my office. I had time to glance at the first page of it hastily, and then thinking I might not have another opportunity for several days I dictated to my stenographer my letter to you of November 2d, and left it to be written out and signed by him for me. I have just this morning returned to the city, and take the first opportunity to make a more formal reply.

I adhere to the general ideas of policy which I expressed to you in conversation and in my former letter.

I do not think the matter is in any situation, however, to require the present consideration of whether or not we are likely to be rivals, and as such injurious to each other. That time may very likely come, and perhaps soon, and as one of those interested in Mr. Edison's patents I shall be ready and disposed towards whatever may seem to be required by good business judment.

I should not allude to any possible contest between our patents except from your having expressed a belief (very proper from your standpoint) that "Mr. Edison's light, if put in operation, must in the end pay tribute" to you.

I am entirely satisfied that the most exhaustive search of what has been done by others will show that Mr. Edison has produced a perfectly novel invention.

Very truly yours,

G. P. Lowrey.

Albon Man, Esq.,
3 Mercer St.,
City.

The president stated that he had made no reply to either of these letters and did not consider any necessary.

The letter of October 31st, written by the president, referred to in Mr. Lowrey's communication of November 6th, was presented and read as follows:

(Copy)

New York, Oct. 31st, 1878.

Dear Sir: I have to acknowledge the receipt this afternoon of your letter to me of Oct. 30th, inst. We feel very confident of the success of our inventions and the stability of our patents. Some of your people, and if we are not mistaken from Mr. Edison's own laboratory, have seen our light and can attest its excellence, as can also a vast number of people who have thronged to see it. Of course we have not made public all that we have done, nor do we suppose that Mr. Edison has done so; but we do distinctly claim that we are the inventor of all that we use, and that we can show our priority over Mr. Edison and every one else in these inventions, and we cannot but feel from what we see published that many of these inventions are essential to the successful working of Mr. Edison's light.

If we are right, Mr. Edison's light if put in operation must in the end pay tribute to us. At the same time, my dear sir, we do not claim to be all the world nor to contain all the wisdom of it, nor to know in advance all that has been and will be found out about lighting by electricity. Permit me just here to pay what is but just tribute to the ability, skill and inventive talent of Mr. Edison, and to admit that his well-known character in this respect is a great advantage to those attempting to bring his inventions before a public whose confidence in him as an inventor is great. I admit at the same time the high character, standing and wealth of your associates, as you must that of those who are associated with us. I do not permit myself for a moment to think that either you or those associated with you would think of attempting to deprive us by litigation or otherwise of our just rights, notwithstanding any inference to the contrary that might be drawn from your letter. Having thus cleared the ground I have to say that I can see no ground of objection to a union of interests that should do away with antagonism if a fair basis for such a union can be found. But, on the contrary, I can see and I have no doubt the eminent business men who are associated with us in interest would also see that great advantages might be derived to both companies from such a union.

If you will bring about the appointment of a proper committee from your company for the purpose I will see to it that representatives from our company shall meet them as soon as you advise me for the discussion of the subject. The matter may be informal, if you desire it, at first.

I am happy to hear of Mr. Edison's improved health.

In the matter of foreign patents I believe we are all right.

Very respectfully yours,
ALBON MAN.

G. P. LOWREY, DREXEL BUILDING, COR. WALL & BROAD STS., N. Y.

The Treasurer reported as follows :

Receipts from sale of stock and scrip, $2,616 ; money loaned by Mr. Albon Man, $600 ; excess of salary paid Edwin L. Myers, $20.

Total receipts, $3,236.

Total expenditures to Nov. 12th, $2,224.21.

Balance in bank, $1,011.79.

$26,600, scrip in Treasury.

The Treasurer's report was accepted and placed on file.

The Treasurer further reported that for the $600 borrowed for the company from Mr. Man, the Vice-President and Treasurer have signed a demand note.

On motion the action of the Vice-President and Treasurer was approved.

On motion the President was authorized to pay the bill of Edward P. Hampson for a steam engine put up at the Company's workshop, amounting to $401.55, subject to the acceptance of a proposition by said Hampson to replace the present engine by a larger one costing $1,065.

Adjourned.

W. E. SAWYER,
Secretary.

At the regular monthly meeting of the Board of Trustees of the Electro-Dynamic Light Co., held at No. 94 Walker street, on Thursday, Dec. 12th, 1878, adjourned from the 10th ; present, Messrs. Hugh McCulloch, Wm. H. Hays, Jacob Hays, Lawrence Myers, Albon Man and W. E. Sawyer, the President in the chair.

The minutes of preceding meetings were read and approved, together with the interlineations in the minutes

of the special meeting of the Board of Trustees, held Oct. 15th.

The President reported that he had received from W. E. Sawyer an assignment to the company of seven different applications for patents, which he presented as follows :

Electric Lamps	Filed Dec. 2d.
" "	" Nov. 30.
" "	" Nov. 19.
Thermo lamp	" Nov. 25.
Electric lighting apparatus	" Nov. 19.
Electric lighting apparatus	" Dec. 2d.

On motion, the Treasurer was directed to have the assignment recorded in the Patent Office at Washington.

The President reported that, at a special meeting of the Board, held Oct. 15th, on motion of Mr. McCulloch, the President was authorized to procure letters patent in foreign countries upon the inventions owned by the company, provided the expense of procuring such letters patent can be paid by sale of stock of the company ; that he was unable to make such sale of stock, and that therefore the company had not become the owners of the foreign patents, and had no interest whatever therein.

The report was accepted, approved and ordered to be placed on the minutes.

The Treasurer reported to Dec. 10th balance in bank $737.79.

The report was approved and accepted.

The Treasurer further reported that the Company had borrowed of Albon Man $500 on a demand note signed by the Vice-President and Treasurer ; and that the company had borrowed of Jacob Hays $600, for which a demand note had been given by the President and Treasurer.

On motion of Mr. McCulloch, the action of the President and Vice-President in borrowing $500 of Mr. Man and $600 of Mr. Hays was approved.

On motion of Mr. McCulloch, it was

Resolved, that Lawrence Myers be appointed Superintendent of the company, with full power to supervise and direct the business with a view to pushing forward the construction of lamps and other apparatus necessary for practical work under the patents owned by the company; to sell and dispose of the stock or scrip of the company; to communicate and correspond with parties that may desire to become purchasers of the right to use the inventions secured by the patents; and to do whatever, in his judgment, may be necessary to advance the interests of the company in conference with the President, Secretary and Treasurer.

Adjourned.

W. E. Sawyer, Secy.

At the regular monthly meeting of the Board of Trustees of the Electro-Dynamic Light Co., held at No. 94 Walker St., on Tuesday, Jan. 14th, 1879, present Messrs. Hugh McCulloch, Jacob Hays, Lawrence Myers, Jas. P. Kernochan, Albon Man and W. E. Sawyer, the President in the chair, the minutes of the previous meeting were read and approved.

Adjourned.

W. E. Sawyer, Secy.

At the regular monthly meeting of the Board of Trustees of the Electro-Dynamic Light Co., held at No. 94 Walker St., on Tuesday, Feb. 18th, 1879; adjourned from Feb. 11th; present, Messrs. Hugh McCulloch, Jacob Hays, Jas P. Kernochen and W. E. Sawyer, Mr. McCullock in the chair, the minutes of the previous meeting were read and approved.

The report of the Treasurer was presented and ordered to be read at the next meeting.

On motion, it was

Resolved, That the President and Secretary be and hereby are authorized to furnish lamps to applicants upon such terms as may be agreed upon between them and the applicants.

Adjourned to meet at No. 3 Nassau St., on Tuesday, Feb. 25th, at 3 o'clock, P. M.

W. E. Sawyer, Secy.

At an adjourned meeting of the Board of Trustees of the Electro-Dynamic Light Co., held at No. 3 Nassau street, on Tuesday, Feb. 25th, 1879; present, Messrs. Hugh McCulloch, Wm. H. Hays, Jacob Hays, Lawrence Myers, Jas. P. Kernochan, Albon Man and W. E. Sawyer, the President, in the Chair.

The minutes of the previous meeting were read and approved.

The report of the Treasurer was passed over to the next meeting.

The President presented the following paper which was read by the Secretary:

"New York, Feb. 13, 1879.

"It has been agreed by Mr. Sawyer with Mr. H. L. Judd that Mr. Judd should go on at his own risk and cost to make an electro-dynamic machine of the kind invented by Mr. Sawyer upon the understanding that he, Judd, should have ¼ the interest in the invention both in the United States and foreign countries and should be employed to make the machines for this country for the Electro-Dynamic Light Co. at reasonable prices and exclusively for use in the U. S. But Mr. Sawyer, having before then assigned the invention to said company for this country, it is understood that he was acting for said company, subject to its approval, it being also understood that proper provisions would be inserted in the agreement between Mr. Judd and the company for preventing licensing by his ¼ interest, without approval of the company or its officers and for joint account of the owners.

"I personally approve this agreement and will in good faith seek to have it approved and carried out by the Electro-Dynamic Light Co., and have conversed with the other Directors, or most of them, who also promised to vote to carry it out.

(Signed.) ALBON MAN,
W. E. SAWYER."

On motion the action of the President and Secretary in the foregoing arrangement was unanimously approved.

On motion the President and Treasurer were authorized to borrow of all the Trustees, excepting the Secretary, the sum of $500, in proportion to their respective interests.

Adjourned to meet at the same place on Tuesday, March 11th, at 3:30 P. M.

W. E. SAWYER, Sec'y.

TUESDAY, March 11, 1879.

No quorum present. Meeting adjourned to Tuesday, March 18, 1879, at No. 94 Walker St., at 3½ P. M.

W. E. SAWYER, Sec'y.

TUESDAY, March 18, 1878.

No quorum present. Meeting adjourned to Thursday, March 20th, 1879, at No. 3 Nassau St., at 3½ P. M.

W. E. SAVAGE, Sec'y.

NOTE. Minute of meeting of March 20, 1879, copied in evidence above.

At the regular monthly meeting of the Board of Trustees of the Electro-Dynamic Light Co., held at No. 3 Nassau St., on Tuesday, April 8th, 1879, at 3:30 P. M. Present—Messrs. Hugh McCulloch, Wm. H. Hays, Jacob Hays, Lawrence Myers, Jas. P. Kernochan, Albon Man, and W. E. Sawyer; the President in the chair.

The minutes of the previous meeting were read and

approved, a part of the minutes on page 53, having first been amended, to read as follows:

"The Secretary was requested to state in the minutes that the feeder lamp invention made by him at the expense of the company is the property of the company for the United States, to which he hereby agrees and assents, and will make all necessary assignments, provided the company procures the patents upon it within a reasonable time."

The Treasurer reported as follows:

Balance in bank, $2.61.

Total liabilities, $3,666.69, of which amounts there is due:

Albon Man	$1,862 50
Jacob Hays	750 00
Hugh McCullogh	150 00
W. H. Hays	150 00
Lawrence Meyers	150 00
J. P. Kernochan	150 00
Classon & Hays	141 97

Adjourned.

W. E. SAWYER,
Secretary.

A special meeting of the Board of Trustees of the Electro-Dynamic Light Company was held at 94 Walker street, on Saturday, April 19th, 1879, at 3 P. M. Present—Messrs. Hugh McCulloch, Jas. P. Kernochan, Jacob Hays, Albon Man and W. E. Sawyer; the President in the chair.

The reading of the minutes of the previous meeting was dispensed with.

On motion of Mr. McCulloch, the President was authorized to continue the use of the premises at 94 Walker street, for a period of one month or longer, not to exceed three months from May 1st.

Bills of Frasse & Co., and Muller & Newman were presented and approved.

Adjourned to meet at the call of the President or Secretary.

W. E. SAWYER,
Secretary.

A special meeting af the Board of Trustees of the Electro-Dynamic Light Company was held at No. 94 Walker street, on Saturday, April 26th, 1879, at 3 P M. Present—Messrs. Lawrence Myers, Jacob Hays, Albon Man and W. E. Sawyer; the President in the chair.

The minutes of the two previous meetings, held April 8th and 19th, were read and approved.

The President reported as follows:

"That the interference case with Keith and with Maxim arising from the application of Sawyer & Man for a patent for manufacturing carbon for electric lights, which has been assigned to the company, has been proceeded with. The company's attorney, Mr. Broadnax, reports that there is no interference with the claims made in our application for a patent, and that as soon as he can get the testimony of Mr. Maxim (that of Mr. Keith having already been taken, and he disclaiming any claim to the invention for which we have applied for a patent) he can make an arrangement with these parties to have our patent issued, they withdrawing any opposition to it. The attorneys for Maxim and Keith have both expressed themselves as satisfied that there is no interference, and the only object in having Mr. Maxim's testimony now is that he may not in the future be permitted to reissue any patent that he might obtain for his supposed improvement in such manner as to interfere with ours, it being understood by Mr. Broadnax that Maxim will disclaim under oath, as Keith has done, any claim to the invention in that form in which we have made it."

The president further reported that the premises at No. 94 Walker street can only be hired temporarily for office purposes only.

The president further reported that he has received an offer of $125 for the engine and boiler belonging to the company, but that W. E. Sawyer has informed him that a Co. is about being formed for the manufacture of telegraphic apparatus which he thinks would be glad to buy the engine, machinery and tools of this Co. at a fair and reasonable price before a great while, and

he advised that they be allowed to remain where they are for the present. If necessity arises they can be removed to the store of Gillis & Geoghegan in Wooster street, from which they can be advertised and sold if the Co. desires.

The report of the president was accepted and ordered to be entered upon the minutes.

The secretary was requested to enter upon the minutes the fact that "at this meeting the room is illuminated by five feeder lamps manufactured by Mr. Sawyer, and all the trustees present are well pleased with the exhibit."

The secretary reported that he has applied for the patent upon the feeder lamp and presented bill of expenses amounting to $51.80.

The application for patent is entitled "Electric Lamps and Switches Therefor," and its receipt is acknowledged by a letter from the Commissioner of Patents, dated Washington, April 23d, 1879.

On motion of Mr. Meyers it was unanimously

Resolved, That the bill of W. E. Sawyer, amounting to $51.80, for applying for letters patent upon the feeder lamp, be approved and paid.

The secretary further reported that the Commissioner of Patents requires a model of the invention before taking official action upon the feeder lamp application, and on motion of Mr. Hayes the secretary was directed to have the model constructed at the expense of the company as quickly and cheaply as possible.

The secretary further reported that the feeder lamp is now complete, that nothing remains to be done except to manufacture and sell lamps and switches; and there being no necessity for further experimenting, he recommended that the workshop of the company be closed and the machinery and tools sold; that the dynamo machines be located in some place provided with steam power, and that an office be hired in which lamps may be charged and kept on exhibition and the electricity be conveyed by wires from the dynamo machines to the office.

The Secretary stated that it is impossible for him to make long carbons for the feeder lamps out of materials at hand and that it is absolutely necessary to order a supply from France at once.

The Secretary recommended that the immediate construction of twenty feeder lamps and switches at Mr. Judd's factory, or elsewhere.

The reports, statements and recommendations of the Secretary were received and ordered to be entered upon the minutes.

The Secretary individually made the following proposition:

That if the members of the Board desire to resume the position occupied by them previous to the meeting of March 20th, 1879, at which W. E. Sawyer's proposition to pay off the debts of the Co., etc., was made and accepted, he (Mr. Sawyer) will co-operate with the other members of the Board in bringing about that result upon the following basis:

First. W. E. Sawyer to be reimbursed for all the moneys expended by him on his own account for the 6 weeks ending April 29th, amounting to $800.

Second. The Company to pay him $3,500, and he will assign for the same $3,500 of his stock and scrip in the Company, and this sum of $3,500 shall be for his salary as electrician of the Co. for one year.

Third. W. E. Sawyer to have the privilege of buying back the above $3,500 of stock and scrip within one year at par, and he will give his services to the Co. as electrician for the coming year without further consideration.

Fourth. A sale to be made of a sufficient amount of the scrip of the Company now in the treasury to provide the sum of $2,500 to be used exclusively for the manufacture of lamps and to pay the expenses of their exhibition, over and above the existing debt of the Co. and other expenses, according to the intention of the Secretary in making this proposition.

Fifth. W. E. Sawyer, as electrician of the Company, to have exclusive charge and direction for one year of all work connected with the manufacture, charging and putting up of lamps, and all electrical work, subject only to the direction of the Board of Trustees.

Sixth. That an understanding be arrived at respecting the sale of rights, increasing the capital stock of the Co., and admission to the Co. of certain capitalists with whom W. E. Sawyer has been negotiating to carry out his proposition of March 20th.

It was understood by the Secretary that decisive action is to be taken upon the foregoing proposition previous to the Secretary's departure from New York on Tuesday night or Wednesday morning next.

On motion it was resolved that the Secretary's proposition be entered upon the minutes and taken under consideration.

Adjourned to meet at the call of the President.

W. E. Sawyer, Secretary.

The regular monthly meeting of the Board of Trustees of the Electro-Dynamic Light Co. was held at the office of Classon & Hays, No. 11 Nassau St., on Tuesday May 13th, 1879, at 3 o'clock P. M. Present-- Messers. Albon Man, Lawrence Myers, Jas. P. Kernochan, Jacob Hays, and W. H. Hays; the President in the chair.

Mr. Myers was elected Secretary *pro tem*, and he reported that Mr. Hugh McCulloch desired him to act for him in his absence.

The reading of the minutes of the previous meeting was dispensed with.

The President reported that Mr. W. E. Sayer believes that he can make an arrangement with Mr. Thomas Wallace, of Ansonio, Conn., to go on and build and sell the lamps of this Co. in lots of six lamps or less, and to pay the Co. a royalty of three dollars per lamp.

On motion it was

Resolved, that Mr. Albon Man be reimbursed for a dynamo-electric machine perchased by him for the Company.

The President reported that he had sold the Co.'s steam engine for $165, and odds and ends of no further use to the Co. for $30.69, and that he has stored the remainder of the property of the Co. in a store-room over his own office; that he has paid out bills against the Co., for which vouchers are rendered, $86.98, leaving in the hands of the Treasurer $108.71.

The President further reported that Man & Parsons, lawyers, will accept $250 in payment of their bill.

On motion, it was

Resolved, that Mr. Joseph Tait be paid $200 for keeping the books of the Co. for one year from July 15th, 1878.

Adjourned to meet at the same place on Wednesday, May 14th, 1879, at 2:45 P. M.

W. E. Sawyer, Secretary.

At an adjourned meeting of the Board of Trustees of the Electro-Dynamic Light Co., held at No. 11 Nassau St., on Wednesday, May 14th, 1879. Present—Messrs. Albon Man, W. H. Hays, Jacob Hays, Lawrence Myers, J. P. Kernochan and W. E. Sawyer; the President in the chair. The minutes of the meeting held April 26th, 1879, and of the meeting held May 13th, 1879, were read and approved.

Mr. W. E. Sawyer gave formal notice that he shall not carry out the proposition made by him on the 20th of March, 1878, relative to a reorganization of the Company, and that he withdraws such proposition.

Adjourned to meet at the call of the President and Secretary.

W. E. Sawyer, Sec'y.

At a special meeting of the Board of Trustees of the Electro-Dynamic Light Company, held at No. 11 Nassau street, on Tuesday May 20th, 1879.

Present—Messrs. W. H. Hays, Jacob Hays, Lawrence Myers, Albon Man and W. E. Sawyer. The President in the chair.

The reading of the minutes of the previous meeting was dispensed with.

The President stated that the notice of the meeting had been sent to all of the Trustees, and said:

"I hold in my hands and present to you, gentlemen, the resignation of Mr. Jas. P. Kernochan, as a trustee of this company."

The letter of resignation of Mr. Kernochan was read by the Secretary, as follows:

(Copy.)

"To the President and Trustees of the Electro-Dynamic Light Company:

"Gentlemen—I beg hereby to offer my resignation as a trustee of the Electro-Dynamic Light Co.

"And hoping that our Company may meet with full success under the new organization.

"I am truly yours,

"Jas. P. Kernochan.

"New York, 19th May, 1879."

On motion of Mr. Jacob Hays the resignation of Mr. Kernochan was accepted, and on further motion of Mr. Hays, Mr. Thomas Wallace was unanimously appointed a trustee of this company in place of Mr. James P. Kernochan, resigned.

Mr. Wallace being present, the President formally notified him of his appointment, and Mr. Wallace accepted the position.

The President also presented the resignation of Mr. W. H. Hays as one of the trustees of the company, and the letter of resignation was read, as follows:

(Copy.)

"To the President and Trustees of the Electro-Dynamic Light Company:

"Gentlemen—I beg hereby to offer my resignation as a trustee of the Electro-Dynamic Light Co., and hoping that our Company may meet with full success under the new organization.

"I am truly yours,

"W. H. Hays.

"New York, May 19, 1879."

On motion of Mr. Jacob Hays the resignation of Mr. Wm. H. Hays was accepted.

On further motion of Mr. Jacob Hays, Mr. Uri T. Hungerford was unanimously appointed a trustee of this company in place of Mr. Wm. Hays, resigned; and the Secretary was directed to notify Mr. Hungerford of his appointment.

The President then formally tendered his resignation as president of the company, while thanking the Board for the courtesy and appreciation of his services uniformly shown him.

On motion of Mr. Jacob Hays, the resignation of Mr. Man as President was accepted; and Mr. Man having, before the acceptance of his resignation, appointed Messrs. Jacob Hays and W. E. Sawyer tellers to receive and count the ballots for his successor, balloting for a new President of the Company was on motion proceeded with, and the tellers reported as follows:

For Mr. Thomas Wallace as President, four votes and one blank.

Mr. Wallace being then declared duly elected President of the Company in place of Mr. Albon Man resigned, briefly thanked the gentlemen present and took the chair.

Mr. Man then said:

"Mr. President and Gentlemen of the Board of Trustees: I hold a promissory note of Mr. Thomas Wallace for $5,000, given to the Treasurer of the Electro-Dynamic Light Company in payment for scrip contributed by the former Trustees of the Company for the purpose of paying off the debts of the Company. We have received this note with the understanding that it shall not be discounted or go out of the hands of the Treasurer or his house, in some way, so that Mr. Wallace can at any time take it up; but it is desired that the affairs of the Company be closed up, and to that end I move that the Treasurer be authorized to apply this note to the extinguishment of the debts of the Company."

The President declared that such a course would be satisfactory to him, and on motion it was

Resolved, That the note of Mr. Thomas Wallace for $5,000 be used for paying off the debts of the Company.

Mr. Man then said:

"The question arises, gentlemen, in regard to going on with the manufacture of our lamps. I suppose that, in accordance with Mr. Sawyer's understanding, Mr. Thomas Wallace, or his house, proposes to go on and build a lot of these lamps and put them out experimentally."

The President said in reply:

"My idea of this matter was that the house that I am connected with—Wallace & Sons, who are fitted up for this electrical work—should add this lamp to the business they are already doing in this direction; that they should use their present machinery for manufacturing, and facilities for introducing this lamp as widely and generally as it is possible to do, and that the connection between that house and the Company would be that they should pay for every lamp made and sold a royalty to this Company. That will simplify the business of this Company. It is simply to receive a royalty, have correct books of account kept and sworn statements made, and the royalties paid right into the Company, and that is according to the understanding I had with Mr. Sawyer, and I presume it has been so understood. Mr. Sawyer asked me to look the matter over and I thought, myself, after looking the thing over carefully, that three dollars per lamp would be about the proper royalty to be paid. I should be satisfied to pay that royalty. I should be satisfied as a stockholder of this Company and as a stockholder of Wallace & Sons."

On motion of Mr. Man it was then unanimously

Resolved, That Wallace & Sons be authorized to build and put up the lamps and other apparatus of the Company, paying to the Company a royalty of three dollars per lamp for such lamps as they shall put up until some further and more positive arrangement can be made.

A bill of H. L. Judd & Co. of $60 for work and materials was presented, approved and ordered to be paid as soon as there shall be sufficient funds in the Treasury.

Mr. Man then presented the resignation of Mr. Lawrence Myers as a Trustee of this Company, carrying with it his resignation as Vice-President of the Company, and the letter of resignation was read as follows:

(Copy.)

"New York, May 19th, 1879.

"To the President and Trustees of the Electro-Dynamic Light Co.:

"Gentlemen—I beg hereby to offer my resignation as a Trustee of the Electro-Dynamic Light Co., and hoping that our Company may meet with full success under the new organization.

"I am, Truly Yours,
"L. Myers."

On motion of Mr. Jacob Hays, the resignation of Mr. Myers was accepted and on motion of Mr. Man,

Mr. John B. Wallace was appointed a Trustee of this Company in place of Lawrence Myers, resigned.

The Secretary was directed to notify Mr. Wallace of his appointment.

On motion of Mr. Man the Board proceeded to the election of a Vice-President to fill the vacancy occasioned by the resignation of Mr. Meyers, and the tellers, Messrs. Hays and Sawyer, reported as follows:

That three votes had been cast for Albon Man and one blank, and Mr. Man was declared duly elected Vice-President of the Company.

Adjourned to meet at No. 11 Nassau St. on the second Tuesday of June next, at 3 o'clock P. M.

W. E. Sawyer, Secy.

The regular monthly meeting of the Board of Trustees of the Electro-Dynamic Light Co. was held at No. 11 Nassau St. on Tuesday, June 10, 1879, at 3 o'clock P. M. Present—Messrs. Thomas Wallace, Uri T. Hungerford, Albon Man, Jacob Hayes and W. E. Sawyer, the President in the chair.

The reading of the minutes of the two previous meetings was dispensed with.

Mr. Dow, attorney for Messrs. Wallace & Sons, of Ansonia, Conn., presented and read the draft of a license between this Company and Messrs. Wallace & Sons, and on motion, Messrs. Hugh McCulloch, Albon Man, Jacob Hayes, Thomas Wallace and Uri T. Hungerford, were unanimously appointed a Committee to draw up such a license as this Company is willing to give Messrs. Wallace & Sons for the right to manufacture and sell lamps under the Company's Patent; and the Vice-President, Mr. Albon Man, was unanimously authorized to sign such license on behalf of the Company.

Adjourned.

W. E. Sawyer, Secy.

Defendant's counsel objects to the answer of the witness on the same grounds as stated in his objection to the question, and gives notice that before or at final hearing he will move to strike the same from the record.

Cross-examination closed.

Hugh R. Garden.

Sworn to before me this 12th day of March, 1889.

John H. Kitchen,
Examiner.

End of Garden's McKeesport Deposition.

GEORGE W. SAWYER'S McKEESPORT DEPOSITION.

UNITED STATES CIRCUIT COURT,

WESTERN DISTRICT OF PENNSYLVANIA.

THE CONSOLIDATED ELECTRIC LIGHT COMPANY
vs.
McKEESPORT ELECTRIC LIGHT COMPANY

UNITED STATES CIRCUIT COURT,

SOUTHERN DISTRICT OF NEW YORK.

THE CONSOLIDATED ELECTRIC LIGHT COMPANY
vs.
THE EDISON ELECTRIC LIGHT COMPANY and THOMAS A. EDISON.

STATE OF NEW YORK,
City and County of New York. } ss.:

Be it rememberad, that on this 20th day of February, in the year of our Lord one thousand eight hundred and eighty-nine, I, William T. Farnham, a notary public in and for the City, County and State of New York, under and by virtue of the statutes of the United States in such cases made and provided, did call and cause to be and personally appear before me, George W. Sawyer, pursuant to the annexed notice, at the Mitchell House, on the corner of Broadway and Forty-

second street, in the said City of New York, in said County and State, to testify and the truth to say on the part and in behalf of the defendant in certain suits, or matters of controversy, now depending and undetermined in the Circuit Court of the United States for the Western District of Pennsylvania, wherein The Consolidated Electric Light Company is complainant and the McKeesport Light Company is defendant, and in a suit or matter of controversy now depending and undetermined in the Circuit Court of the United States for the Southern District of New York, wherein The Consolidated Electric Light Company is complainant and the Edison Electric Light Company and Thomas A. Edison are defendants.

Present—Thomas B. Kerr and Amos Broadnax, counsel for complainant The Consolidated Electric Lighting Co., Walter K. Griffin, Esq., and Richard N. Dyer, Esq., for the defendants The McKeesport Electric Light Company and the defendants The Edison Electric Light Co. and Thomas A. Edison.
Also present Albon Man.

And the said George W. Sawyer, being about the age of twenty-seven years, and having been by me first cautioned and sworn to testify the truth, the whole truth and nothing but the truth in the matter of controversy aforesaid, I carefully examined the said George W. Sawyer, and he did thereupon depose, testify and say as follows, viz.:

Counsel for complainant requests counsel for respondent to permit Dr. Charles A. Bucklin, residing at 206 West Forty-second street, and who is now present, to examine the witness on behalf of the complainant with reference to his physical and mental condition before the examination proceeds.

Counsel for defendants accede to the request.

(Dr. Bucklin was then permitted to enter the room and examine into the witness' condition, being in the presence of counsel for both the complainant and defendants.)

Examined by Mr. Griffin:

1 Q. What is your name, age and present place of residence?

A. My name is George W. Sawyer; age twenty-seven; I am at present residing in the Mitchell House, New York City, under medical treatment.

2 Q. Are you the George W. Sawyer who is the brother of William Edward Sawyer. one of the joint patentees of the patent in suit, and are you also the George W. Sawyer who, before this, testified in certain interference proceedings between Messrs. Sawyer and Man and Mr. Edison in the Patent Office?

A. I am.

3 Q. Please look at the book marked for identification "Defendant's Exhibit A, Feb. 20, 1889, and state whether you recognize the same, and whether you have examined it (handing book to witness)?

A. Yes, sir.

Defendant's counsel requests of record that the notary mark the book for identification, as stated in the question tc witness.

4 Q. With the exception of pages 49 to 56, inclusive, and the first eight lines of page 57, in whose handwriting are the various entries in the book?

A. The other handwriting is my brother's—William E. Sawyer.

5 Q. Please look at the entries on pages 123 to 129 of the book, and state in whose handwriting the entries on those pages are?

The question is objected to as immaterial and incompetent unless the book is going to be offered in evidence.

A. It is all my brother's writing.

6 Q. Have you seen this book before, and if so, how did you first see it?

A. It came to me through my brother, in some way, at some different time; it was left in my care; anyway I came by it, and I have had it.

7 Q. How long; how many months or how many years?

A. I have had the book since before 1880 or 1881.

8 Q. How long were you employed with your brother, William Edward Sawyer, in his experiments on electric lamps and similar things?

A. On all of his electrical experiments.

9 Q. Yes?

A. About 1871 or 1872—until 1881 or 1882. I won't be quite sure; there was lapses of about a year, in the meanwhile, when I might not have been with him. I first commenced with him in Washington.

10 Q. When were you with your brother in Washington.

A. In 1871 or 1872.

11 Q. Were you with your brother all the while during these years you have named, or from time to time?

A. With him most of the time; lived with my mother, my sister and myself; as a rule, most of the time.

12 Q. After you left your brother, whose employment did you go into?

A. I never was in any ones employment but his, or where he was employed.

13 Q. Were you with your brother before he became acquainted with Albon Man?

A. I was.

14 Q. And after you became acquainted with him?

A. Yes, sir.

15 Q. What part did you take with the various experiments that your brother made in electric lights, or electric lamps?

A. I was with him in most all of his experiments, assisting him, bringing apparatus to him such as he would want to use, and assisting him in any way that I could.

16 Q. Do you know Hiram S. Maxim, S. D. Schuyler, James Flannigan, J. G. Smith, and others?

A. I do.

17 Q. Had these gentlemen any association with your brother in his experiments in a business way?

A. Yes, sir.

18 Q. Had your brother and Mr. Schuyler and Mr. Maxim any business connection?

A. Yes, sir.

19 Q. In what class of business was this?

A. In electric motors and postal telegraph.

20 Q. Do you remember any experiments made by your brother at the Coal and Iron Exchange?

A. Coal and Iron Exchange?

21 Q. Yes?

A. I do.

22 Q. How much apparatus had your brother at the Coal and Iron Exchange for making electrical experiments?

A. A very little, only a few cells of battery, a couple of flasks with stoppers or tubes running up through, which held a piece of carbon, and we would charge the flask with illuminating gas, that is all.

23 Q. Prior to the time that Mr. Man became acquainted with your brother, had your brother or any one connected with him made anything that you could call an electric lamp?

A. No, sir.

24 Q. How far had your brother got—what had he done in experimenting that way?

A. Nothing more than heating up pieces of carbon to incandescence in the air.

25 Q. What sort of carbon was this?

A. Generally lead pencil; held it up in the air.

26 Q. Do you remember E. P. Benjamin, dealer in chemical apparatus, in Barclay street, New York City.

A. I do.

27 Q. Did you ever purchase anything from him for your brother?

A. Yes, sir.

28 Q. What did you purchase?

A. Florence flasks.

29 Q. How many?

A. I don't think more than two at a time; I don't know as I ever purchased more than two while he was at the Coal and Iron exchange.

30 Q. What did your brother do with these flasks at the Coal and Iron Exchange?

A. As I said, we had a couple of uprights put up in them—conductors—to hold the piece of carbon; I think we tied the carbon around with copper wire so as to make a connection, and there was a rubber cork in it; we took the lamp down to the Merchants' Hotel—was it the Merchants' that used to be below Church street? A very old house; I don't think it is there now.

31 Q. You took them down to the hotel?

A. We took them down to the hotel, and charged them, and came up and tried them.

32 Q. What kind of gas was used in the lamp?

A. Illuminating gas; I know we were very much afraid that they were going to explode, and we wanted to get out of danger.

33 Q. How many of these lamps were burning, or tried to be brought to a light?

A. We tried both of them.

34 Q. About how long did the burning last?

A. Well, the globes became smoked so that we couldn't tell anything about it, and we opened them and looked at them.

35 Q. What kind of carbon did you use in these lamps?

A. I won't be positive whether it was this retort carbon or lead pencil carbon.

36 Q. Do you remember about what the date of these experiments was?

A. Somewhere in February, 1878.

37 Q. Had your brother ever made any experiments with the electric lamp for incandescence before that time to your recollection?

A. No, sir; I am very sure his experiments all date from the 1st of February or latter part of January.

38 Q. Was Mr. Man present when those experiments were made?

A. Not this first one; no, sir. The first time Mr. Man was present was on Washington's Birthday, the 22d of February. I am very sure of that.

39 Q. And when Mr. Man was there was the experiment different from what it was before?

A. No, sir.

40 Q. After your brother moved to Centre street and while he was there, were you with him in his employ?

A. Yes, sir.

41 Q. How many flasks or lamp glasses did you buy for use at Centre street, as you best remember?

A. I know that we had seventeen of them up there at one exhibition; they lasted no length of time at all; we were very glad to get the crowd out that was in there before everything would play out.

42 Q. What do you just mean by that; that you were glad to get them out?

A. Before everything would play out. It had a kind of partial success, and that was all, for probably half an hour.

43 Q. What would you do with the lamps after the people had left?

A. Take them down again. The carbons kept getting larger, and the globe darkened and the light dimmer.

44 Q. Do I understand you that you would put in new carbons after the people left?

A. Use the same carbon and recharge it.

45 Q. Recharge them?

A. Recharge them with gas.

46 Q. Was the glass plain transparent glass in these 17 or 18 globes?

A. Some of them were ground and others were transparent.

47 Q. What was your object in using ground glass?

A. To diffuse the light—show a difference.

48 Q. What kind of a machine for developing electricity did you have at Centre street?

A. An Arnoux & Hochhausen machine, situated in the basement of the place when we got there; that is how we came to go there.

49 Q. How long did you use this machine that was situated in the basement?

A. I think only a few days; they took it away themselves.

50 Q. What did you use after that?

A. There was a Ball machine, I think, and a Weston in there, but there was nothing done with those; we used to take a lamp in there to the little shop corner of Howard and Mead—not Howard and Mead—a little corner up there that Arnoux & Hochhausen had, and they were running a machine then, trying to get one that would heat up a piece of metal so that we could use it.

51 Q. What kind of apparatus had you for conducting experiments at Centre street?

A. Only crude.

52 Q. How much; do you remember?

A. Charcoal furnace—these furnaces that they use for heating a tube—chemists use them; I don't know the name of them. They got it there to heat a tube filled with copper turnings; it didn't work. They use it for quicksilver.

53 Q. How often were you with your brother in Centre street, in the shop?

A. I was there continuously—all the time, except when out on errands, with the exception of one space of time when I was away at Washington filing some patents for him.

54 Q. How long do you think that you were away?

A. Might have been a month; still I don't think it was a month.

55 Q. How often would Mr. Man be at the shop in Centre street?

A. Sometimes for a short time in the morning, and again in the afernoon.

56 Q. Did he ever do any work in the shop that you saw?

A. Not much more than talking or consulting with my brother.

57 Q. About how many lamps do you think were made or used in Centre street during the time you were there?

A. I cannot recollect that.

58 Q. Give your best memory as to whether there were a great many or very few?

A. There were very few; we never had a great many.

59 Q. What would your idea be of a great many?

A. There may have been ten lamps put up there at Centre street.

60 Q. What difference was there between the lamps you used at Centre street and the lamp which you mentioned you had experimented with at the Coal and Iron Exchange?

A. A different way of sealing the bottoms so as to make it tight, and the conductor that went up inside to keep it from loosening the sealing through the conduction of heat. It was a soapstone bar put in at that time; we only had the one workman working at the lamp there; that was my father.

61 Q. Were the lamps used with illuminating gas as they were at the Exchange?

A. They were charged with different gas; some with illuminating gas, and then I think we had some with nitrogen. I don't know as we had any with other than illuminating gas.

62 Q. You have mentioned a stopper for the flasks or lamps what kind of a stopper did you use at Centre street. What was it made of?

A. Glass.

63 Q. Who made the globes and covers or caps?

A. Mr. Man got the globes from Brooklyn, I think, some place.

64 Q And do I understand you that the globes and their fittings were not made at Centre street?

A. We had no apparatus for making glass there.

65 Q. How about the fittings; were those made there?

A. The fittings were made there.

66 Q. What kind of carbon was used in these lamps in Centre street?

A. Hard carbon, retort carbon, worked into shape.

67 Q. Was the resistance of these carbons high or low?

A. It was very low.

68 Q. How large were the carbons—were they large or small?

A. Well, might have been ¾ of an inch long, and filled out a sixteenth of an inch or more.

69 Q. Did you give an exhibition of these lamps in Centre street?

A. Yes, sir.

70 Q. Just state what you remember about that exhibition?

A. That was when we first went there from the Coal and Iron Exchange. I know that I was sent around to the newspaper office and telegraph, steamship companies, and invited all those different men—head men—there to this Exhibition. There didn't near as many come as we expected. After they were there we started up; I think it was about three o'clock in the afternoon. We ran along until the lamps commenced to grow dimmer and dimmer, and I don't know how my brother excused them; he managed to have a reason, anyway, for shutting down and getting them out; he was very glad to get them out.

71 Q. Did you notice anything about the carbons after the exhibition was over?

A. Yes, sir; they had all increased in size.

72 Q. What remark did your brother make as regards this increase of size, if any?

A. I don't know as he made any remark—that is, to me personally.

73 Q. After the exhibition did you alter the style of fittings of your lamp at all?

A. No, sir; not the style of fittings; we were continually experimenting there at all time—made one lamp—no more than one lamp at a time.

74 Q. How did you close the lamp, as you have mentioned. What did you use to close the lamp?

A. It seems to me they had this flat stopper at this time, and fir balsam put in the joint, and the joint was clamped together; there was a flange cast on the upper globe, and there was some kind of metal clamp to clamp the stopper and globe together.

75 Q. Of all these lamps that you have mentioned up to the time you left Centre street, do you remember any other carbon than hard carbon, or retort carbon, that you have mentioned being used?

A. No, sir.

76 Q, Did you ever see or hear of anything else being used in the lamps?

A. No, sir.

77. Q. What is the longest time that you remember any lamp burning at Centre street continuously—I mean at one time?

A. I do not believe we ever burned a lamp there over half or three-quarters of an hour at a time.

78 Q. What opportunities did you have of knowing?

A. I being there.

79 Q. Suppose visitors came there, what was your custom in showing them the lamps?

A. Turn it on; start a machine up and turn it on. After they were in the place for half or three-quarters of an hour, then you can turn it out without them thinking much about it?

80 Q. What, if anything, would you do to the lamps after the visitors had gone?

A. If there was anything necessary, we repaired it.

81 Q. What is the longest time that you remember a lamp being burned without having the carbon renewed or the globe recharged with gas?

A. I cannot recollect that, because there was none of them burned very long at a time; just what time it would figure up that they had been there I couldn't say.

82 Q. Did you ever see any carbon made at Centre street or see any substance carbonized?

A. No, sir.

83 Q. Did you have any means of carbonizing materials at Centre street?

A. No, sir.

84 Q. Was the charcoal furnace that you mentioned at all adapted for carbonizing?

A. No, sir; it was a plumber's furnace.

85 Q. Was there any fireplace in the room?

A. No, sir.

86 Q. How was the room heated?

A. Steam pipes.

87 Q. When you moved from Centre street to the corner of Howard and Centre, what did you do there?

A. They were experimenting there on distribution. I think my brother got up a switch there, and all gases for the lamps.

88 Q. Were the carbons used at the corner of Howard and Centre streets any different from the carbons used at Centre street?

A. I don't think so.

89 Q. Have you any recollection of any other carbons being used than the hard or retort carbon?

A. No, sir.

90 Q. You moved from Howard street to the corner of Walker and Elm streets, I believe, did you not?

A. Yes, sir.

91 Q. How much of the time that your brother was at Walker street were you with him?

A. I was there continually from early morning to late at night. In fact, as long as there was any one there.

92 Q. What was your employment there specially?

A. I took care of the engine there, and boiler, and ran errands.

93 Q. What machinery had they there; I mean mechanic's machinery?

A. They had a lathe.

94 Q. How many lathes?

A. One or two, and a grinding-stone, I think.

95 Q. Did they have any special apparatus for electrical experiments?

A. Well, they had a kind of chemical set there.

96 Q. At the shop at Walker and Elm street, how often was Mr. Man present, and what did he do?

A. He was present almost every day. Sometimes he remained for an hour, sometimes he would be there quite a while. Seeing to his own business, that occupied a great deal of his time.

97 Q. What class of carbon was used in the lamps at Walker street?

A. I think we got the French carbon then, but I will not be sure I think we had a few sticks of the French carbon, but retort carbon was our principal one.

98 Q. What kind of gas, if any, was in the lamps?

A. We charged them with nitrogen gas and the vacuums.

99 Q. How much of a vacuum did you get in any of the lamps?

A. I think my brother used to claim that there was one per cent. air left in the globes.

100 Q. What success did you have with the lamps when they had any vacuum instead of being filled with gas?

A. I don't know as we really used the vacuum; I think the method of charging our lamps was, we used to exhaust and allow the gas to flow in and exhaust and allow the gas to flow in again and obtain the vacuum, as we called it, by dilution. Whether they used an absolute vacuum or not, we called it a vacuum because there was no air.

101 Q. Do I understand that you got rid of the air and filled the lamps with gas, so that only one one-hundedth part of air would be present in the gas?

A. Yes, sir.

102 Q. Did you see any lamps in which the air was taken out and nothing put in?

A. Yes, sir.

103 Q. How long were those tried?

A. Well, I can't state just the length of time. They were never tried very long, because they never run long. The carbon was always disintegrating.

104 Q. How did these succeed as compared with other lamps? I mean the one with the air which you have mentioned?

A. I don't think as well as those charged with nitrogen gas. You couldn't seem to get enough vacuum.

105 Q. How did you try to get the vacuum that you did get?

A. We had a fall of water from the roof of the house —I don't know what they call it—water carried up to a tank in the top of the house and through its fall by another pipe it sucks air.

106 Q. Do you remember your brother working upon what he called a feeder lamp, and if so, when do you remember his first beginning to work on these?

A. I thing it was at Walker and Elm streets.

107 Q. What importance did your brother attach to the feeder lamp?

A. So that the lamp would not have to be taken apart every time in order to have the carbon replaced.

108 Q. What kind of carbon was used in the feeder lamp?

A. Retort carbon.

109 Q. Did you ever know any other kind of carbon used in the feeder lamps at Walker street?

A. No, sir.

110 Q. Was any carbonizing done at Walker street?

A. I think there was some willow twigs carbonized there, that Mr. Man brought.

111 Q. Do you remember anything else being carbonized there except willow twigs?

A. No, sir.

112 Q. What did they do with these willow twigs or sticks after they carbonized them?

A. Worked them down into the shape that they wished them, but it strikes me that they never amounted to anything because they were of too high resistance for our machine, the machine would not accumulate upon them, they didn't seem to be dense enough.

113 Q. How did they work as compared with the hard carbons?

A. I can't recollect that, but not as well.

114 Q. What was the shape of these willow carbons when you used them?

A. They made them in different shapes.

115 Q. Just tell us the different shapes ?

A. They were generally a straight round pencil about that length (witness indicates about three-quarters of an inch between his fingers).

116 Q. How many of these twigs do you remember being actually used in any of the lamps ?

A. I can't remember how many ?

117 x-Q. Were there many or few ?

A. Few.

118 Q. Did they keep on using these willow twigs ?

A, No, sir.

119 Q. What did they do after they ceased to use the willow twigs ?

A. They experimented continually on different forms of carbon—different shapes—different forms of lamps.

120 Q. Was this use of willow carbon experimental, or did they make any considerable number of lamps or use any considerable amount of time with the willow carbon ?

A. No, sir.

> Objected to by the counsel for complainant on the ground that the witness is not in the position to know.

121 Q. What means of knowledge had you of the extent of use of the willow carbons at Walker street, as you have testified ?

A. Why, from seeing them put into the lamps and the lamps run.

122 Q. Could the lamps have been run without your knowledge at Walker street ?

A. No, sir ; not more than, maybe half an hour at a time ; not more than that.

123 Q. With the exception of the French, or retort carbon, and the willow carbon, do you remember any other kind of carbon being used at Walker street in the lamps ?

A. No, sir ; I remember they tried to obtain other carbons, but they met with no success.

124 Q. Just state what you mean by their trying to obtain other carbons ?

A. They tried to permeate blotting paper with the lead, or plumbago of a lead pencil, and then heat them up with the machine and carbonize them, which cannot be done, as a plating machine would not accumulate on a thing of such high resistance.

125 Q. Did you ever see carbonized paper used in a lamp at Walker street, or at Centre street ?

A. No, sir.

126 Q. I don't know whether I have asked you whether you ever saw a willow carbon, or any vegetable carbon, there at Walker or Centre street, of an arched or horseshoe shape ?

A. Yes, there were carbons worked into that shape there. One in particular I know we had. Whether we had more than one that was set up at the time, I do not know ; I think we did, but I know of this one. At the time of the Edison publication of the horseshoe lamp, it was taken down and placed in the hands of the New York "Tribune" people—I think it was the "Tribune," it was some newspaper or other—but that was of hard carbon worked into that shape. The reason this was done was on account of diffusing the light, so that it would show a larger light—the incandescent part of the carbon will show a great deal larger. I only saw this at Walker street, I didn't see it at Centre street. I thought you were talking of Walker and Elm streets.

127 Q. Did you ever see any lamp with vegetable carbon or paper carbon having the arched or horseshoe shape ?

A. No, sir.

128 Q. Were these carbons you have mentioned treated, or were they used untreated ?

A. Generally treated.

129 Q. What do you mean by treated ?

A. Immersed in some hydro-carbon oil, or in a hydro-carbon gas—illuminating gas.

130 Q. What was then done ?

A. Immersed in that, and heated up to a state of incandescence.

131 Q. Do you know your brother's habits, as to applying for letters patent for inventions he made?

A. He was very prompt if he had the money. If he had an invention, he always was very sure to raise the money as soon as he could, to obtain the patent.

132 Q. Who drew up the most of his specifications?

A. Himself.

133 Q. What were his means during the time he was in Centre street and Walker street?

A. I guess they were rather limited, except what money he obtained from Mr. Man. I used to get a check once a week from Mr. Man to pay expenses.

134 Q. Did you ever know of his not applying for a patent because he hadn't the money to apply for it?

A. No, sir.

135 Q. Did your brother, at any time prior to the Edison publication in the "New York Herald," ever speak to you of paper carbon or vegetable fibrous carbons of any kind as being important, or in any special degree useful?

A. No, sir.

136 Q. To your knowledge, what carbon did he rely upon in the series of inventions you have mentioned?

A. Carbon of very low resistance.

137 Q. What kind of material?

A. Well, carbon.

138 Q. Was it French retort or the vegetable or paper?

A. About all we knew anything about was the retort carbon.

139 Q. Coming down to the "Herald" publication of Sunday, December 21st, 1879, describing the invention of Edison electric lamp with the carbon horseshoe burner, did you read that article?

A. I did.

140 Q. When?

A. The same morning.

141 Q. Did your brother read it, to your knowledge?

A. He did.

142 Q. What did he say in regard to that article?

A. He didn't believe it at all; it couldn't be done. There was nothing to it.

143 Q. Have you read a printed letter in the New York "Sun," December 22d, 1879, which bears your brother's name, in regarn to Mr. Edison's invention?

A. I have.

144 Q. Did you have any conversation with your brother as to what is stated in that letter?

A. No, sir: except what he had stated in it. I heard him express himself at different times about the challenge he made, and that he believed that he was perfectly right doing it; that he had a sure thing and nothing of the kind could be done.

145 Q. How many times did your brother talk in this way to you about Mr. Edison's invention?

A. He never talked to me personally; generally there was my father in the office ond also one of the other workmen, or Mr. Church. He would express himself to the party, not to me personally.

146 Q. Did you hear him talk this way more than once?

A. Oh, yes.

147 Q. Did your brother ever say anything to you as to whether he wrote that letter published in the "Sun" or not?

A. I knew he wrote it.

148 Q. How do you know?

A. It was written by a person in Henry Darley's saloon, corner of Walker and Elm streets.

149 Q. Who dictated that letter?

A. My brother. My brother was on a little jamboree at that time, or nervous, so that he couldn't write himself.

149 Q. Did you read a letter bearing the signature of your brother, published in the "New York Herald," December 24th, to which I call your attention?

(Counsel reads to witness letter referred to). Do you remember that letter?

A. I remember the letter—yes, sir. That lamp was made at 94 Walker street.

150 Q. You mean the lamp mentioned in the letter, do you?

A. Yes, sir. That is, the carbon that was placed in the lamp, the globe may not have been made there, but the arch shaped carbon was made at 94 Walker street.

151 Q. Do you know whether your brother wrote the letter published over his signature in the " Herald " of December 24th, to which I have just called your attention?

A. Yes, sir.

152 Q. Did he ever have any conversation with you or in your presence with regard to that letter, or the statements in it?

A. No, sir; but if I am not mistaken, I took that lamp and deposited it myself—put it in the hands of the " New York Tribune," not with Arnoux & Hochhausen.

153 Q. Is that the lamp that you have mentioned before as having an arch shape carbon?

A. Yes, sir.

154 Q. Did your brother state to you his object in sending that lamp?

A. To show that he had had the horseshoe shape, which he believed was the only thing that Edison was after—the shape of the carbon.

155 Q. Did your brother say anything to you about any importance he attached to the material of the burner?

A. No, sir.

156 Q. What was your brother doing at that time, if anything, with the feeder lamp?

A. He was continually experimenting, writing at his desk, figuring at his office.

157 Q. Did you read, at about the time of its publication a letter over your brother's signature published in the " Herald " January 5th, 1880?

Counsel reads from page 455 of the Printed Record of Complainant's Exhibits in the suit of The Consolidated Electric Light Company against The Edison Electric Electric Company. (Exhibit B., taken from the " Herald " of January 5th, 1880).

Do you remember that letter.

A. I do, sir.

158 Q. Do you know whether your brother wrote the letter as it was published in the " Herald " over his signature?

A. Yes, sir; I believe it was published the same as he wrote it; I have no means of knowing differently.

159 Q. Did your brother ever speak to you about writing the letter?

A. I think I was with him when he wrote the letter. I was with him mostly continuously. After he left the office, after his supper. I was at his house continually until bedtime, then I went home.

160 Q. What did your brother say as regards Mr. Edison's claims or statements as to his success with the carbon burner in his lamp?

A. Why he never believed it.

161 Q. About this time did you see any of the Edison lamps, or see the illumination of any of the Edison lamps?

A. Yes, sir; I passed Menlo Park—I think my brother sent me out there to ride by to see; how far I rode I don't remember, I think to Monmouth Junction. When I came home I told them they were burning at the Park when I went and also when I came back. Then he said they had made arragements and started and stopped them at train time.

162 Q. I don't quite understand about starting and stopping them at train time; what did your brother say as to that?

A. He said that they started the lamps when a train would be due and after it passed put them out, that is, they were not burned continuously.

163 Q. What did your brother say to you as to Mr. Edison's claim that he had carbonized a thin thread and that he had made a lamp in which such a thread was used as a burner?

A. He laughed at it.

164 Q. Why did he laugh at it?

A. Horse-hair they called it at first.

165 Q, Do you remember a book entitled "Sawyer on Electric Lighting" purporting to have been written by your brother?

A. "Sawyer on Electric Lighting and Incandescence?"

166 Q. Yes, sir?

A. Yes, sir.

167 Q. Do you know whether your brother wrote that book?

A. He did.

168 Q. Going back to the exhibitions of the lamps at Centre street and again at Walker street, you testified substantially that when the visitors had gone the lamps would be turned out and the carbons, if necessary, changed?

A. Yes, sir.

169 Q. What representations, if any, did your brother make to the visitors as to the life of the lamps?

A. Well, that they would, in a practical shape, last forever.

170 Q. Was Mr. Man or Mr. Myers in a position to know how long the lamps actually burned?

A. Mr. Myers was not with us at Centre street.

171 Q. I mean, while he was with you at any time, was he or Mr. Man in a position to know how long a lamp actually burned?

A. Mr. Man was not; Mr. Myers was more so than Mr. Man. Mr. Myers lived out of town and was not there quite so long as the rest of us. Mr. Man was not in a position to know.

172 Q. What representations would your brother make to Mr. Man or Mr. Myers as to the lamps burning continuously?

A. Favorable.

173 Q. Did the statement that he made to Mr. Man represent the facts or not?

A. Sometimes they represented the facts, but very often they did not.

174 Q. What do you mean by "very often they did not?"

A. Well, that very often they did not represent the facts. He told about lamps running such a length of time when they hadn't.

175 Q. Did your brother ever state what his object was in making these statements to Mr. Man?

A. No, sir.

176 Q. You have stated that you have previously testified in the interference case, please state how you came to testify in that case?

A. That was at Mr. Broadnax's office, was it not?

177 Q. Yes, sir; I mean in the interference proceedings between Sawyer & Man and Thomas A. Edison, on the paper carbons?

A. I was told I should come down there and remember this and that, that was all I would have to do; I should be questioned a little, that is all. I think I was not asked more than six or seven questions before I was out. I was cautioned what to say and what not to say.

178 Q. Who gave you these cautions as to what to say and not to say?

A. I think my brother.

179 Q. Did Mr. Man speak to you as to the testimony you should give?

A. Often.

180 Q. What did he ask you with regard to your testimony?

A. Well, not with regard to the testimony I should give, but he often tried to convince me that such and such was the case.

181 Q. Did your brother try to convince you also that such and such was the case?

A. No, sir.

182 Q. You stated that you were at present at the Mitchell House for medical treatment; please state how you came here and who is paying the expense of your stay and medical attendance at this house?

A. Mr. Russell met me at Lehighton, Penn., some months ago and found me in a very low condition. I told him I was not getting proper medical treatment, and that if I could go to New York and see a prominent doctor there and have a change of climate, it would be beneficial to me. He said he would see that it was done. I understand, in fact I know, that The Edison Electric Light Company is paying the expenses of my time here and medical attendance—not time, but medical attendance.

183 Q. You mean that they are paying all your expenses here in New York?

A. All my expenses here and all my medical attendance.

As this testimony in direct has been taken in shorthand, by consent, and it being impossible for the typewriter to give counsel a copy for some time, the further examination of the witness is adjourned until to-morrow, February 21, 1889, at eleven o'clock A. M., at the same place.

MITCHELL HOUSE, 42d St. and B'way,
NEW YORK, February 21, 1889.

Met pursuant to adjournment.

Present—Same counsel and parties as before.

DIRECT EXAMINATION OF GEORGE W. SAWYER CONTINUED BY MR. GRIFFIN:

184 Q. In your answer to the 79th question yesterday you stated that you thought your brother used to claim that there was only one-hundredth per cent. air left in the globes; what do you mean by that; how much air did you understand your brother to claim was left in the globes?

A. Well, now, I think it was that way, one hundredth per cent., as he stated it.

185 Q. What do you mean by that?

A. One one-hundredth.

186 Q. Do you mean by that one one-hundredth part?

A. Of the entire contents of the globe was air. One one-hundredth—I wouldn't be sure which, now.

187 Q. When did your brother's experiments at Walker and Elm streets end?

A. I think some time in 1879, just which date I can't now recollect.

188 Q. What was the occasion or reason of the experiments ending?

A. I think there was some trouble with the company, or that the company hadn't the facilities for carrying out the work there. They took it to Ansonia.

189 Q. Did Mr. Man continue with your brother at Ansonia?

A. I don't recollect of Mr. Man ever being at Ansonia. I went up there before my brother two or three days, and took some lamps and other paraphernalia along.

190 Q. What class of work was your brother engaged on at Ansonia?

A. Mostly in winding and rewinding the Wallace-Farmer machine.

191 Q. Were there any experiments made on lamps that you remember at Ansonia by your brother?

A. Not while we were there; not while I was there.

192 Q. How long were you there with your brother, to your recollection?

A. It is a very hard thing for me to recollect now.

193 Q. Was it three months, or six months, or a year?

A. No, sir; it was not. I don't think it was three months.

194 Q. Do you remember your brother making any further experiments on lamps after you gave up at the corner of Walker and Elm streets, up to the time of the publication of the Edison article in the "New York Herald"?

A. No, sir.

CROSS-EXAMINATION BY MR. BROADNAX, SOLICITOR, AND OF COUNSEL FOR THE COMPLAINANT:

195 x-Q. How did you come to be a witness on behalf of the Edison Electric Light Company in this case?

A. Through my own free will.

196 x-Q. Who asked you to be a witness first?

A. I think Mr. Russell.

197 x-Q. Who is Mr. Russell?

A. He is a gentleman that I have known for six or seven years.

198 x-Q. Known him intimately?

A. Well, not very intimately; at the same time we are very friendly.

199 x-Q. Was he a friend, also, of your brother, William E. Sawyer?

A. Not that I know of, sir.

200 x-Q. Where was Mr. Russell when he asked you to become a witness in this case, and where were you?

A. I met Mr. Russell first in New York.

201 x-Q. When?

A. It must have been, anyway, six or seven years ago.

202 x-Q. He didn't ask you then to be a witness in this case. did he?

A. We were talking electric lights, and such and such goings on.

203 x-Q. You said you met Mr. Russell in Lehighton?

A. This last time, yes, sir.

204 x-Q. How did you happen to meet Mr. Russell there?

A. I sent for Mr. Russell.

205 x-Q. You sent for Mr. Russell?

A. Yes, sir.

206 x-Q. By letter?

A. By letter.

207 x-Q. Have you a copy of the letter you wrote to Mr. Russell?

A. No, sir, I have not.

208 x-Q. Have you got the letter yourself?

A. No, sir.

209 x-Q. Do you know where the letter is?

A. I don't know as I do now, because letters are something that I kept no record of whatever.

210 x-Q. Why did you send for Mr. Russell?

A. On account of being in straightened circumstances, and wishing to see if I couldn't be benefited in some way or other, and knowing that he was a friend of mine, and probably could help me.

211 x-Q. Did you say anything to him then about being a witness in this case?

A. No, sir.

212 x-Q. Did he say anything to you about it?

A. No, sir.

213 x-Q. When did he first speak to you about becoming a witness?

A. I cannot recollect.

214 x-Q. What did he say to you?

A. I cannot recollect that—the words.

215 x-Q. Can you give me any idea what Mr. Russell said to you when he asked you to be a witness here?

A. No, sir; but I think it was voluntary on my part.

216 x-Q. In volunteering to be a witness, what did you say to him?

A. I cannot recollect the exact words, sir.

217 x-Q. Give the substance of it?

A. I don't know as I could give the substance of it.

218 x-Q. What arrangements did you make with Mr. Russell about testifying?

A. No arrangements whatever.

219 x-Q. You came without making any arrangements?

A. Yes, sir.

220 x-Q. Was Mr. Russell acting on behalf of the Edison Electric Light Company?

A. I couldn't say.

221 x-Q. He didn't say anything to you, then, about testifying on behalf of the Edison Electric Light Company?

A. No, sir.

222 x-Q. You just came here of your own motion ?

A. I came here to obtain better medical treatment than I was receiving at the place where I was.

223 x-Q. And you made no arrangements with him at that time, when you left Leighton, about testifying in this case?

A. No, sir. None whatever.

224 x-Q. When did you first make your arrangements with him about testifying in this case ?

A. I cannot recollect, sir.

Q. 225 x-Q. About how long was it ?

A. I cannot recollect the exact time ; it is impossible for me to remember.

226 x-Q. I didn't ask you to state the exact time?

A. I cannot recollect any time to state a positive time when it was ; I might say ten years ago, which it couldn't have been, and I might say it was five years, which it might have been.

227 x-Q. Was it five years ago when you made the arrangements?

A. It might have been five years ago.

228 x-Q. When you made your arrangements to testify in this case ?

A. It might have been five years ago.

229 x-Q. Was there any case pending then ?

A. Not that I know of, sir.

230 x-Q. Then it could scarcely have been five years ago?

A. I think it was all of five years ago, anyway.

231 x-Q. Since you agreed to testify for the Edison Company?

A. Since I may have said anything that I could tell them that would help justice along I was willing to do.

232 x-Q. Did you tell them that ?

A. I think I told Mr. Russell that.

233 x-Q. Who did you tell that to ; Mr. Russell ?

A. I think so ; yes, sir.

234 x-Q. You have testified that the Edison Electric Light Company are paying your expenses here. How does that company happen to be paying your expenses?

A. I don't know. Mr. Russell said that he would try and make arrangements so that he would raise enough money to have me have the proper medical treatment here.

235 x-Q. And he made the arrangements with the Edison Electric Company?

A. He made the arrangements, and since then I have ascertained myself that it was that company that were paying for my medical attendance and expenses.

236 x-Q. And you don't know why they are paying your expenses?

A. No, sir, I do not.

237 x-Q. Mr. Russell has never told you anything about that?

A. No, sir.

238 x-Q. And yet you are here testifying for them, and they are paying your expenses?

A. Yes, sir.

239 x-Q. And you have no knowledge as to how you came to be here to testify?

A. Why, I think I clearly stated that I came here for proper medical treatment.

240 x-Q. You came here for medical treatment, but you are here testifying for the Edison Electric Light Company, and they are paying your expenses?

A. I can't see as that should signify anything.

241 x-Q. That to your mind doesn't seem to signify anything, as I understand you ?

242 x-Q. Did you have any consultation with Mr. Edison's lawyers previous to your coming here ?

A. No, sir.

243 x-Q. Never saw any of them before?

A. No, sir.

244 x-Q. All your consultations were with Mr. Russell ?

A. Yes, sir.

245 x-Q. Did you make an affidavit in this case before you came here?

A. No, sir.

246 x-Q. Did you make one after you came here?

A. No, sir.

247 x-Q. Did you make an affidavit in this case at all ?

A. No, sir.

248 x-Q. Did you make any statement in writing, or did you make any statement that was taken down in writing about the case?

A. No, sir.

> Counsel for the defendants states thathe thinks the witness does not understand the question; that he probably refers to his coming the last time.
>
> Counsel for the complainants states that he refers to his coming at any time.
>
> THE WITNESS: I was under the impression that you meant since I came here for this medical treatment; I supposed you were talking about the last time.

249 x-Q. How did the gentleman, who examined you yesterday get a long type-written statement from which he conducted your examination?

A. That, I think, was from a statement that I made some five years ago.

250 x-Q. Where was that statement made?

A. In New York.

251 x-Q. To whom?

A. To Mr. Tomlinson, I think.

252 x-Q. Counsel for the Edison Company?

A. I don't know whether he was counsel for the Edison Company or not. I was not well acquainted with any of these parties at all.

253 x-Q. Whereabouts were you when you made these statements?

A. I think at their place in South Fifth avenue, or Fifth avenue, wherever the company's place is. I cannot recollect now; near Fourteenth street.

254 x-Q. Do you mean to be understood as saying that you made your arrangement to testify in this case with Mr. Tomlinson, five years ago?

A. I merely made a statement of facts that I knew; made no arrangements to ever testify in it.

255 x-Q. Did you have no understanding with Mr. Tomlinson that you would testify to the facts that you gave to him for his client?

A. When I told him that I knew those facts, I said I would make them known at any time they wished me to; that is all the answer I should consider that required.

256 x-Q. What did Mr. Tomlinson give you for the certificate that you made to him at that time?

A. Nothing, sir.

257 x-Q. Did he make any arrangements to give you anything?

A. I think my expenses were paid while I was here in New York; that, I believe, was all.

258 x-Q. Who brought you here at that time to make that statement to Mr. Tomlinson; I mean at whose request did you come here?

A. On my own request first, until I met Mr. Russell.

259 x-Q. Did you go and see Mr. Tomlinson of your own motion?

A. No, sir; I was in straitened circumstances myself.

260 x-Q. And you went to see Mr. Tomlinson to get money?

A. No, sir; I didn't see Mr. Tomlinson at all; I saw Mr. Russell.

261 x-Q. Did Mr. Russell help you out of your straitened circumstances?

A. Yes, sir.

261½ x-Q. Who furnished the money?

A. I couldn't state who furnished the money.

262 x-Q. What is Mr. Russell's name in full?

A. James; that is all that I know of. He has a middle letter, but I don't remember now just what it is. James A., I think; I wouldn't be sure, though.

263 x-Q When did you say you made his acquaintance first?

A. When did I say I made his acquaintance first?

264 x-Q. Yes.

A. It might have been five or six years ago; I think it was all of that.

265 x-Q. Was that the time you had your first interview with Mr. Tomlinson ?

A. No, sir ; I had met Mr. Russell before—long before that.

266 x-Q. Was Mr. Russell in the employment of the Edison Electric Light Company ?

A. That I couldn't say. I never knew whom he was employed by.

267 x-Q. Did you make your arrangements with Mr. Russell, or were the arrangements made for your interview with Mr. Tomlinson through Mr. Russell ?

A. Through Mr. Russell.

268 x-Q. Through Mr. Russell ?

A. Yes, sir ; through Mr. Russell.

269 x-Q. How was that brought about ?

A. I couldn't say.

370 x-Q. Did Mr. Russell first see you about having an interview with Mr. Tomlinson ?

A. No, sir ; I first saw Mr. Russell, not about having an interview with Mr. Tomlinson personally, but with the Edison Company.

271 x-Q. What was said between you and Mr. Russell at the time of that conversation ?

A. It is so long ago that I cannot recollect now.

272 x-Q. What was the substance of your interview ?

A. I couldn't state.

273 x-Q. Cannot you state what was said that brought you to testify, or to make your statement to Mr. Tomlinson ?

A. No, sir.

274 x-Q. Why did you go to see Mr. Russell, and where did you go to see him ?

A. I think I have already stated that I went to see Mr. Tomlinson or Mr. Russell because I was in straitened circumstances and wanted to see whether I could raise a little money for myself—borrow it from him, or if he could borrow it from somewheres for me.

275 x-Q. And did he borrow it from somebody for you ?

A. I don't know whether he borrowed it or not. What I wanted I got—the small sum that I wanted.

276 x-Q. How much was it ?

A. I will not state.

277 x-Q. Do you refuse to state how much ?

A. That was a matter of private business of my own ; I don't think it concerns this case in any way at all.

278 x-Q. You are not the judge of that ; we are the judges of that. You will please to answer my question —state how much ?

A. It may have been $100 ; it may have been less, or it may have been more.

279 x-Q. How much was it, as a matter of fact ?

A. I cannot recollect the exact sum.

280 x-Q. State as near as you can recollect ?

A. I have.

281 x-Q. You cannot state the amount ?

A. No, sir ; I cannot.

282 x-Q. You cannot state it approximately ?

A. I cannot.

283 x-Q. Is your testimony which you have given now in accordance with the statement you made to Mr. Tomlinson at that time ?

A. I don't understand you, Mr. Broadnax.

284 x-Q. Is the testimony which you gave yesterday and to-day, so far, in accordance with the statement you made to Mr. Tomlinson some four or five years ago ?

A. I think so.

Before closing the examination of this witness, counsel for the complainant ask the question whether the book which was shown the witness and identified by him, but not submitted to counsel for the complainant, is to be offered in evidence, and an opportunity given to examine this witness in regard to the same, both as to the writing which he has identified and as to his possession, and as to the nature of the contents.

Defendant's counsel says, that the book is marked for identification only, and refers the complainant's counsel to the record, whereby it will appear that no question as to the contents and no proof as to the accuracy or truth of the contents was asked or required from the witness, but simply an identification of the contents, whatever they may be, as being in the handwriting of the witness' brother, William E. Sawyer.

Counsel for complainants object to questions 3 to 7 as incompent, unless the book is offered in evidence and the witness submitted to cross-examination, and they give notice to the counsel for the defendants, that in view of the refusal to produce the book and permit examination of the witness in regard to the writing which he has identified in reference to certain pages, as well as in reference to the contents of the book and his possession of it, that at 10 o'clock on Saturday, February 23d, a motion will be made before the Court, in Pittsburgh, to strike out so much of the testimony of this witness as relates to said book.

285 x-Q. You have stated that you were examined as a witness in the interference between Thomas A. Edison, on the one side, and Sawyer & Man on the other: have you read your deposition in that case recently?

A. No, sir.

286 x-Q. Has it been read to you?

A. No, sir.

287 x-Q. Do you know what you testified to in that case?

A. I think I can recollect pretty well, but I won't be sure that I can, it is so long ago; I know it took place in your office and was very short.

288 x Q. I find your deposition in that case printed among the exhibits in the case between the Consolidated Electric Light Company, complainant, and the Edison Electric Light Company and Thomas A. Edison, defendants, pending in the United States Circuit Court for the Southern District of New York, and numbered 3553, such deposition being as follows:

"George W. Sawyer, a witness called on behalf of Sawyer & Man, being duly sworn and interrogated by Mr. Broadnax, testified as follows:

"1 Q. What is your name, age, residence and occupation?

"A. My name is George W. Sawyer; am twenty-three years of age; reside at Earle's Hotel; my occupation is working for the Eastern Electric Manufacturing Company.

"2 Q. Please state where you were employed during the months of October, November and December, 1878?

"A. At 94 Walker street, by the Electro-Dynamic Light Company.

"3 Q. State whether you are acquainted with William E. Sawyer and Albon Man?

"A. I am, with both of them.

"4 Q. State what relation you are to either of them, if any?

"A. Brother of Wm. E. Sawyer.

"5 Q. State whether or not, during that time you were employed at 94 Walker street, you saw there in operation what is known as the Sawyer & Man Electric Lamp?

"A. I did.

"6 Q. State what your duties were at the works of the Electro-Dynamic Light Company at 94 Walker street?

"A. Employed to take care of the boiler and engine, and operate them.

"7 Q. State whether or not, during the time you were employed there, you saw Mr. William E. Sawyer or Albon Man carbonize any paper for the purpose of making carbon burners for their electric lamp?

"A. Yes.

"8 Q. Which of them?

"A. Mr. Man.

"9 Q. Who assisted Mr. Man?

"A. Edwin L. Myers.

"10 Q. Where is Edwin L. Myers?

"A. Dead, I believe.

"11 Q. How did Mr. Man carbonize the paper?

"A. By first cutting the paper to the proper shape; then put it in the retort made of fire clay or graphite; one was made of fire clay and one of graphite; put it in the boiler furnace and made it red hot; then took it out and let it cool gradually; then took the carbons out and used them in the lamp.

"12 Q. Did you see him put them in the lamps?

"A. Yes.

"13 Q. Which month was it you saw them do this?

"A. In the latter part of October, and in the months of November and December.

"14 Q. What shape was the retort?

"A. One, I believe, was three-cornered and one was round; was about five or six inches long; they put the papers in the retort and then filled up with powdered carbon.

"15 Q. How many lamps did you see them put these carbons in?

"A. A number of them. I could not say how many.

"16 Q. Did you see those paper carbons illuminated in the lamp?

"A. Yes.

"17 Q. How long were they illuminated?

"A. I can't say how long; I did not pay any especial attention to that.

"18 Q. State, as near as you can recollect, how long you had been at work at 94 Walker street before you saw Mr. Man carbonizing paper as you have stated?

"A. Very shortly after we moved there; how long I cannot say.

"19 Q. Was it a week or two weeks?

"A. Think it was about a week; it is very shortly after we moved there.

"20 Q. Did you see Mr. Man or your brother, Wm. E. Sawyer, making, or causing to be made, any carbonized paper for burners for their electric lamps at any other place besides 94 Walker street, and if so, where?

"A. I think at 43 Centre street, in April or March.

"21 Q. Were you employed at 43 Centre street?

"A. Yes, sir.

"22 Q. In what capacity?

"A. As an errand boy;

"23 Q. Did you see them carbonize the paper?

"A. No, sir.

"24 Q. Did you see the paper after it was carbonized there?

"A. Yes.

"25 Q. How do you know that the paper was made of carbon?

"A. They laid it on the table, and I was told they were carbonized paper.

"26 Q. Who told you they were carbonized paper?

"A. My brother, Wm. E. Sawyer.

"28 Q. Did you see any of these carbon burners that your brother told you were made of carbonized paper used in the electric lamps at 43 Centre street?

"A. We had several lamps in use there, but I don't know whether the carbons used in the lamps were made of paper or not.

"28 Q. Was it at the time that your brother, W. E. Sawyer, and Albon Man were experimenting with their lamps at 43 Centre street that your brother told you that the carbons were made of carbonized paper?

"A. Yes, sir.

Cross-examination by Mr. Dyer, of Counsel for Mr. Edison:

"29 x-Q. Then you do not know of your own knowledge that any carbonized paper conductors were made at 43 Centre street?

"A. No, sir.

"30 x-Q. Where was the boiler room at 94 Walker street—what part of the building?

"A. In the northwest corner of the workshop?

"31 x-Q. Was all the carbonizing done there done in the furnace of the boiler?

"A. Yes, all that was done in the shop.

"32 x-Q. Were other things carbonized besides paper?

"A. Yes.

"33 x-Q. What other things?

"A. Willow twigs.

"34 x-Q. Anything else?

"A. Not that I remember.

"35 x-Q. What was the proportion of the paper to the twigs?

"A. Could not say.

"36 x-Q. How far away from where you were working were the materials prepared for carbonization?

"A. Perhaps twenty feet.

"37 x-Q. Did you see any paper packed in retorts for carbonization at that shop?

"A. Yes.

"38 x-Q. Who packed it?

"A. Mr. Man, and Mr. Edwin L. Myers.

Re-direct Examination by Mr. Broadnax;

"39 Re-d. Q. State if you recollect, what kind of paper was used for carbonization?

"A. Paper that looked like blotting paper.

"George W. S. Sawyer."

Q. Did you give that testimony?

A. I testified in the interfence case at Mr. Broadnax's office, and what you have quoted in my testimony in that case.

Counsel for complainant request and demand that defendant's counsel furnish them with a copy of the statement made by the witness to Mr. Tomlinson, as stated by him in his deposition, four or five years ago, and upon which they examined the witness upon his examination-in-chief, in full sight of the counsel for the complainants.

It is consented between counsel that the examiner, Mr. Farnham, may sign the witness name to the deposition.

George W. Sawyer.

Sworn to before me,

William T. Farnham.
[L. s.] Notary Public,
County and State of New York.

I hereby certify that the name of the witness, George W. Sawyer, was signed by me pursuant to the consent herein before entered on the record.

William T. Farnham.
[L. s.] Notary Public,
County and State of New York.

End of George W. Sawyer's McKeesport Deposition.

SHARP'S McKEESPORT DEPOSITION.

New York, February 28, 1889.

Met pursuant to adjournment.

Present—R. N. Dyer, Esq., and W. K. Griffin, Esq., for defendant, and L. E. Curtis, Esq., for complainant, and Mr. Albon Man.

William Sharp, a witness called on behalf of defendants, and duly sworn, testifies as follows:

1 Q. What is your name, age, residence and occupation?

A. William Sharp; about fifty-three years of age; was born July 31st, 1835. I live at 14 Pleasant place, Brooklyn; I am a chandelier maker.

2 Q. Were you in the employment of Messrs. Sawyer & Man when they had their workshop at No. 2 Howard street, New York City?

A. Yes, sir.

3 Q. Prior to that time had you done any work for Mr. Man on any electrical apparatus?

A. Yes, sir.

4 Q. Where did you do it and what was it?

A. At my residence in Brooklyn; I believe that it was two lamps.

5 Q. Describe them?

A. Well, one was an inclosed glass with two holes at the bottom to put the working parts of the lamp through. They were put together at the holes with a kind of a clamp or washer, I should call it. Then it was screwed together. I can't exactly think how it was screwed together. There were two nuts on the bottom. I think I have given it all about as near as I can think of it.

6 Q. Did you make any burners for these lamps, and if so, state what they were?

A. I can't remember just what the burner was in that lamp.

7 Q. What was it made of?

A. Well, I can't just remember what it was. I can't just tell how it was put together.

8 Q. I do not refer to the metal parts, but to the burner or part to be lighted by electricity. What was it made of?

A. I believe that that was a cross piece holding a pencil of carbon.

9 Q. What kind of carbon?

A. Retort; gas retort.

10 Q. What did you do to this gas retort carbon, if anything?

A. I don't remember of putting that carbon in that lamp.

11 Q. Did you make the carbon?

A. No; I don't think I had anything to do with the carbon in that lamp.

12 Q. Did you do any work at Brooklyn on carbons for Mr. Man; if so, what was it?

A. I turned a small disc of retort carbon.

13 Q. State exactly everything you did to the carbon, from the beginning to the end?

A. I got a small piece of carbon and filed it down flat; then I turned the carbon to somewhere about a thirty-second part of an inch thick. It was turned to about a half an inch in diameter, I believe, with a hole in it about a quarter of an inch in diameter.

14 Q. Did you work on any other piece of carbon for a lamp in Brooklyn for Mr. Man?

A. I don't believe I did.

15 Q. Was Mr. Man at any time present while you were at work on these lamps?

A. Yes, sir; he was there very frequently.

16 Q. Did he superintend your work?

A. Yes, sir.

17 Q. Where did you deliver these lamps?

A. I delivered those lamps to Mr. Man at my residence.

18 Q. About how long in all were you working on these lamps?

A. That I couldn't say very plainly.

19 Q. Is that all your answer?

A. Yes, sir.

20 Q. Would it be a week, or a month, or three months, or what?

A. I couldn't say. It might perhaps be a month or six weeks.

21 Q. How long after you finished your work on these lamps was it that you were first employed at Sawyer & Man's workshop at Howard street?

A. I couldn't say that for certain. It might perhaps be about a month.

22 Q. How large a room did Mr. Sawyer have at Howard street?

A. Well, at Howard street, I couldn't say. We were working in a shop with other men; in the shop of Arnoux & Hochhausen.

23 Q. Did Mr. Sawyer have a room of his own?

A. He had a kind of an office there about ten foot square.

24 Q. What kind of furniture was in the office?

A. There was a desk or a table something similar to this (witness pointing to the table on which the Master is writing). There was a chair.

25 Q. Was there any work-bench or tools for a workshop in the office?

A. Not that I know of, any further than a kind of gasometer they had there.

26 Q. Did you ever do any work in the office?

A. No, sir; I never done any work further than to go down and see Mr. Sawyer one time. He wanted some one in the room in case anything might happen to the gasometer, or something similar to it, while he was working it.

27 Q. Who besides yourself did work for Sawyer & Man while you were there at Howard street?

A. Mr. William Sawyer.

28 Q. Where did he work?

A. I believe he worked on the same bench that I did. We were close together.

29 Q. Was this in Arnoux & Hochhausen's shop?

A. Yes, sir.

30 Q. Who supplied the tools for you to work with?

A. We used to use Arnoux & Hochhausen's tools and the small tools was principally our own.

31 Q. Were you employed by Sawyer & Man while they were at the corner of Walker and Elm streets?

A. Yes, sir.

32 Q. How soon after they moved there were you working there?

A. I suppose about a couple of weeks after they had left Arnoux & Hochhausen's.

33 Q. During these two weeks where were you working?

A. I was working at Arnoux & Hochhausen's.

34 Q. For whom?

A. Arnoux & Hochhausen.

35 Q. After you went to Walker street how long did you remain there at work?

A. I couldn't say how long I remained there. I remained there till they broke up the business.

36 Q. Were you employed by Mr. Sawyer after he left Walker street?

A. Well, I worked for Mr. Sawyer after Sawyer & Man dissolved, so far as I know of it.

37 Q. Where did you continue to work for Mr. Sawyer?

A. In the same room.

38 Q. And after that?

A. After that I went up to Ansonia with him. Mr. Sawyer made arrangements with the firm of Wallace & Sons, at Ansonia, Conn.

39 Q. While you were at Howard street and at Walker street were you at work continuously from day to day or only occasionally?

A. I was working continuously from day to day.

40 Q. What were the working hours?

A. Ten hours a day.

41 Q. What rooms did Sawyer & Man have at Walker and Elm streets?

A. They had one large room partitioned off pretty near the middle; one part was their office, the other part was the workshop. There was a recess in the side where the water closet, the boiler and engine was.

42 Q. How many windows were there in the workshop?

A. Two.

43 Q. Were they any work benches; if so, where were they placed?

A. There was one bench in front of the two windows and the chemist bench in the end of the room.

44 Q. Was this chemist bench at the partition end or the other end of the room?

A. The other end of the room.

45 Q. How did the chemist bench run, in what direction?

A. It run east and west.

46 Q. And the work bench?

A. North and south.

47 Q. Who worked on the work bench?

A. Mr. William Sawyer and myself.

48 Q. What part of the bench did you work at?

A. I worked on the north end of it.

49 Q. Was this the end near the chemical bench, or the other end?

A. Near the chemical bench.

50 Q. What machinery did Sawyer & Man have at Walker street?

A. They had a small dynamo, a lathe, a grindstone, a boiler and engine. I might say there were two vises in there?

51 Q. Who provided most of the tools?

A. Outside of the lathe and vises, we furnished our own tools pretty much.

52 Q. Was there any machinery in the office?

A. No, sir; not that I know of.

53 Q. What was in the office?

A. I don't remember anything further being there than a desk, and a couple of chairs, and a chandelier.

54 Q. Did you ever see any work done in the office?

A. Nothing further than filing down some carbons.

55 Q. Where did you see this done?

A. On the end of the table.

56 Q. Who was doing it?

A. Edward Sawyer.

57 Q. What was your work at Walker street; what were you employed at?

A. Principally making parts of lamps.

58 Q. Who finished or mounted the lamps?

A. I believe I done a good part of it—towards the last part of it; put them together with Mr. Myers' assistance.

59 Q. Did you work on the burners?

A. Principally all burners, for anything I know. I can't designate any parts.

60 Q. What do you mean by "burners" in your answer?

A. I consider the whole concern a burner.

61 Q. What did you call the part which gave the light when heated up?

A. That is the carbon.

62 Q. Did you work on the carbons?

A. Sometimes I used to file them down—get them of proper length and size.

63 Q. What did you make the carbons from when you filed them?

A. The carbons that I filed on was filed from long strips of carbon in the shape of wire, ranging from about a sixteenth to somewhere about three-sixteenths in diameter.

64 Q. What was the name of these long strips?

A. I did not know that they had any name, further than that I understood that they were imported from France.

65 Q. What sort of carbon were they?

A. They were hard carbons, similar to what they burn in these arc lamps.

66 Q. How hard were they?

A. They were not quite as hard as glass, but they would break quite as easy.

67 Q. What was the shape of these long strips?

A. Round.

68 Q. Were they straight or crooked?

A. Straight.

69 Q. Take the pen and make a sketch of the size to which you filed down these carbons?

(Witness does so).

A. I have done so as above.

70 Q. How near does your sketch come to the size of the carbon?

A. I should think it would come in between the inside of one line and the outside of the other line.

71 Q. How about the length of the carbon?

A. I think the sketch is about the length as near as I can think of it.

Adjourned till 2 o'clock P. M.

Resumed at 2 o'clock P. M.

72 Q. When these carbons were put in the lamps on what did they rest?

A. They rested on a larger carbon point.

73 Q. What were these larger carbon points made of?

A. They were made of the crude carbon?

74 Q. What kind of crude carbon?

A. Gas retort carbon, I believe it is.

75 Q. Did you see any other kind of carbon than the gas retort carbon and the French carbon?

A. No, sir.

76 Q. Were any of the carbons made out of the gas retort carbon?

A. Which carbons do you mean?

77 Q. I mean the pencils burnt in the lamps.

A. I can't remember whether there was any of them made out of the crude carbon or not.

78 Q. What do you remember seeing any pencils made out of?

A. I don't remember seeing them made out of anything excepting that imported carbon.

79 Q. Did they use gas retort carbon for any purposes; if so, what?

A. They used it for making the holders for these pencils.

80 Q. Who used to make the holders?

A. I think I used to make them principally.

81 Q. Who else?

A. I don't remember whether Wm. Sawyer had anything to do with making them or not.

82 Q. You have stated that you have made a circular carbon for Mr. Man in Brooklyn. Did you make any circular carbons while working for Sawyer & Man, either at Howard or Walker street?

A. I made two or three while we was in Walker street.

83 Q. What tools or machinery did you use to make them?

A. Make them with a lathe, with a face plate and files and small turning tools.

84 Q. What was the size of these circular carbons?

A. I don't remember very distinctly, somewhere from a half inch to three-quarters.

85 Q. Was that in diameter?

A. Yes, sir.

86 Q. How thick were they?

A. About a thirty-second of an inch thick.

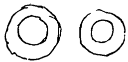
87 Q. What was the inside diameter?

A. That is something I don't distinctly remember.

88 Q. How large a tool did you use to make the hole in the center?

A. Small hand turning tools.

89 Q. Sketch the size and shape of these carbons as finished by you as near as you can remember?



A. That is about as near as I can get at it.

90 Q. What kind of carbon were these circles made of?

A. They were made of retort carbon.

91 Q. What was done with these circles?

A. I don't remember what was really done with it, one was put in a lamp and the other two, or rather there was one half a one put in a lamp. The other two I don't know what became of them.

92 Q. What do you mean by one half of the circle being put in a lamp?

A. They was cut in two so as to form a half circle between the two holders.

93 Q. What kind of a lamp did you see this half circle put into?

A. It was into a long tube-shape lamp, the same as the majority of the lamps made there.

94 Q. What kind of holders were used for the half circle?

A. I think it was clamped carbon holders.

95 Q. What were the clamps made of?

A. Retort carbon.

96 Q. How were they held in place?

A. By means of two platinum screws and nuts.

97 Q. Who made these platinum screws and nuts?

A. I did.

98 Q. Who made the lamp or lamps in which these half circles were used?

A. I think likely I must have made them.

99 Q. Were the holders for the half circle arranged

differently or the same as the holders for the straight pencils you have mentioned?

Objected to as bad in form, instructive to the witness, and leading.

A. The holders to the half circles was flat, clamped together with two platinum screws and nuts.

100 Q. How did this arrangement compare with the arrangement for holding the straight carbon pencils?

A. Well, in the circle carbon we had two upright clamps; for the straight carbons there was one upright round carbon and one horrizontal.

101 Q. Could you use the half circles with the holders for the straight pencils?

A. Not very well.

102 Q. How many lamps, if any, did you see with the holders arranged for half circles?

A. Not more than one distinctly.

103 Q. Which one was that?

A. I cannot say, with the exception of that one we have just been speaking of.

104 Q. Which one do you mean?

A. The one with the upright clamps, the flat clamps.

105 Q Did you ever see any other circles or half circles of carbon, or curved or circular pieces of carbon, besides the circles you have just said you made yourself?

A. No, sir; I can't remember that I have seen any.

106 Q. Did you ever see any one working on circles or half circles of any material, besides yourself?

A. No, sir.

107 Q. Nor any curve or circular carbon of any kind?

A. No, sir.

108 Q. Did you ever see any of the lamps with the holders arranged for straight pencils altered over or changed in any way for circular or bent carbons?

A. No, sir; I don't know that I have.

109 Q. How near you did Mr. Sawyer, Sr., work?

A. About four or five feet; let me see; it is more than that. It was near the length of the bench.

110 Q. Was there any partition between you?
A. No, sir.
111 Q. Was his work hidden in any way?
A. No, sir.
112 Q. How far did you work from where Mr. Myers worked?
A. About three or four feet.
113 Q. Who worked on the lathe when it was used?
A. Me, principally.
114 Q. Who else?
A. I don't know that any one did. I don't remember of any one.
115 Q. Was Mr. Myers' work in any way hidden from you?
A. I couldn't say that it was.
116 Q. Did you ever work on the same jobs with him?
A. Well, when we was ready to seal the lamps I used to clamp most of them together.
117 Q. What would Mr. Myers do?
A. He used to expel all the air he could get out of the glass before charging them with gas—nitrogen gas, I believe it was.
118 Q. Was there any partition of any kind in the workshop preventing one workman from seeing the work of the others?
A. No, sir.
119 Q. Did you see any attempt made to hide the work of one man from the others?
A. No, sir.
120 Q. Did you see Mr. Man at any time in the workshops?
A. Yes, sir; frequently.
121 Q. What did he do?
A. He used to come round to see whether the work was going on all right.
122 Q. How often was he there that you know of?
A. Generally every day.
123 Q. Did you ever see him doing any work?
A. Well, no work in particular; he might give some suggestions and help us to work it out.
124 Q. What do you mean by suggestions?
A. Suggest some way of making the parts for the lamps.

125 Q. Do you mean suggestions as to doing your work on the lamps?
A. I mean some suggestions as to how he wanted the work made.
126 Q. What kind of work do you remember Mr. Man giving you suggestions as to?
A. In different forms of the patterns on the parts of the lamps.
127 Q. Did you ever see any carbon or charcoal of any kind other than the retort carbon and the French carbon you have mentioned at either of the workshops?
A. I have seen them file down a piece of willow charcoal—willow carbon.
128 Q. Do you know where this willow charcoal came from?
A. I bought some myself on Fulton street.
129 Q. Do you remember the shop?
A. I believe it was Reynolds; I won't be certain, though.
130 Q. What kind of willow charcoal was it?
A. It was in the form of crayons.
131 Q. How large were the crayons?
A. About five-sixteenths of an inch in diameter, about six inches long.
132 Q. What kind of store is Reynolds?
A. Paint and artists' supplies.
133 Q. What did you see done with these charcoal crayons?
A. They were filed down to about the same dimension of the carbon pencils.
134 Q. Do you mean the carbon pencils you made a sketch of?
A. Yes, sir.
135 Q. What was done with them then?
A. There was a deposit of carbon formed over them.
136 Q. Who did this work?
A. Mr. Edwards Myers was the one I saw do it.
137 Q. Did you ever see anybody else do it?
A. I don't remember seeing any one else do it.
138 Q. How did they get the deposit on the charcoal?

A. By putting it into a closed glass vessel with the gas into the vessel and electricity.

139 Q. Do you mean that they put the charcoal into the glass vessel?

A. Yes, sir; put the charcoal in between two metal points.

140 Q. How large were the charcoal crayons after the deposit had been formed upon them?

A. I should judge about an eighth of an inch thick.

141 Q. What did they do with these pencils next?

A. They worked the charcoal core out of the carbon.

142 Q. How was this done?

A. It was done with a piece of wire or head of a file or something. I don't remember exactly how it was done.

143 Q. How much of the charcoal was left in the pencil?

A. Mr. Myers tried to get it all out.

144 Q. Do you know whether he tried to get it all out?

A. That is the way I understood he was doing—trying to get it all out.

145 Q. Did you ever see any willow charcoal or crayons or any form of charcoal or wood carbon used in any way except in forming these pencils as you have just described?

A. No, sir; I don't remember seeing them used in any other way.

146 Q. Did you ever see any wood carbons or wood charcoal of any kind except these willow crayons which you purchased?

A. No, sir.

147 Q. Did you ever see any one at either of the workshops carbonize any material of any sort?

A. No more than willow charcoal.

148 Q. Did you ever see them try to carbonize willow so as to make it into charcoal or carbon?

A. Not that I know of. I don't know what they might be trying in that line.

149 Q. Did you ever see them trying yourself?

A. Trying to make charcoal into carbon?

150 Q. I mean trying to make willow wood into willow charcoal or willow carbon?

A. No; I don't know. They might be trying that; that I wouldn't know anything about.

151 Q. Did you ever see or hear about or work on any carbon made from paper of any kind in either of the workshops?

A. No, sir; I did not.

152 Q. While you were at the workshops did you ever see or work on or see anybody working on or using any carbon of any kind, made from paper of any kind?

A. No, sir.

153 Q. Did you ever hear any one saying that such carbon had been used in any way or tried to be used in any way at either of the workshops?

A. No, sir.

154 Q. When did you first see a piece of paper carbon of any kind?

A. I don't know whether I have seen any particular yet, but I saw them trying it in Ansonia, trying to form carbon out of paper, I guess somewhere about 1880.

155 Q. Whom did you see trying?

A. Mr. William Wallace and Mr. Howell, who was Mr. Wallace's electrician.

156 Q. Was this after or before Mr. Sawyer left Ansonia?

A. Afterwards.

157 Q. State the circumstances under which Mr. Wallace and Mr. Howell came to make or show you the paper carbon, so far as known to you?

A. Mr. Wallace came up into the shop and said that he had read an account in the paper of Mr. Edison inventing a carbon of paper by accident, and they were trying an experiment between themselves in the shop.

Answer objected to as immaterial and incompetent.

158 Q. Did you, while you were at either of the

shops of Sawyer & Man, see any one making or altering any curved, or semi-circular, or circular carbons of any kind except the circles of hard carbon you have testified you yourself made?

A. No, sir.

159 Q. Did you ever, during the same time, hear any talk of any kind as to using curved or circular carbons of any kind, other than the circles of hard carbon you have testified to making?

A. No, sir.

160 Q. About how many lamps of all kinds did Sawyer or Man have at Walker street, so far as you know?

A. Well, I don't know; they seemed to me to be pretty much all one thing. They were generally pencil carbons, straight pencils.

161 Q. How many lamps did they have, so far as you know?

A. I don't know that I have ever seen more than about a dozen at a time.

162 Q. Do you know any time when they had more than a dozen?

A. No, sir; I do not.

163 Q. What did they do to these dozen or so lamps?

A. That I don't know. They used to have exhibitions once in a while.

164 Q. Did you ever know of their selling any.?

A. No, sir.

165 Q. Did you ever see the lamps burning?

A. Yes, sir.

166 Q. Where were they kept burning?

A. Usually in the office.

167 Q. Where else?

A. We had one one time in the shop, trying to work by it.

168 Q. Did you succeed in working by it?

A. No, it was rather too far away from us to see to work good.

169 Q. How long did that lamp burn?

A. Well, I couldn't say how long that lamp burned. It was burned several times, that lamp; it didn't burn any length of time each time.

170 Q. What is the longest you knew it to burn at one time?

A. Not more than twenty minutes to half an hour.

171 Q. What was done to it then?

A. That I couldn't say.

172 Q. What was the longest you remember to have seen any lamp burn at one time?

A. I don't think I ever saw one burn over half an hour.

173 Q. What, so far as you remember, was the general life of a lamp carbon burning in a lamp?

A. As far as my knowledge leads me, I don't think they last more than half an hour.

174 Q. What, if anything, was done to the lamps then?

A. They would be taken apart, cleaned and set up again with new carbons.

175 Q. Did you ever work at doing this?

A. Yes, sir.

176 Q. How frequently?

A. Well, I don't know; pretty nearly every time they burnt out.

177 Q. Did you ever see any willow twigs of any description in either workshop?

A. Yes, sir; I saw them in Walker street.

178 Q. What kind of twigs were they?

A. Green willow twigs three or four feet long.

179 Q. Where did you see them?

A. I saw them in the workshop.

180 Q. Whereabouts?

A. I think they lay in the corner near where I worked.

181 Q. What became of these twigs, so far as you know?

A. I don't know what did become of them.

182 Q. How long did you see them lying around as you have mentioned?

A. I suppose about a month or two.

183 Q. Did you see more than one lot of these twigs.

A. No, sir.

184 Q. Did you ever do any work or see any one do any work on these twigs of any description?

A. Not that I remember.

185 Q. Did you ever see any one at Walker street put anything into the boiler furnace except the coal?

A. Yes, sir; I have seen them with small crucibles with graphite or something in.

186 Q. Do you know what was in these crucibles?

A. No, sir; I do not, further than graphite.

187 Q. How often did you see any crucibles put in the furnace?

A. Not more than three or four times, to my knowledge.

188 Q. Did you ever see any crucibles except those you saw put under the boiler furnace at Walker street around the shop or rooms?

A. No, sir.

189 Q. Did you ever know of any of the contents of any of these crucibles being used in any of the lamps?

A. No, sir; I did not.

190 Q. Did you ever do any work on any material which you knew or were told came out of these crucibles?

A. No, sir.

191 Q. Did you ever see any one work on any of the material which came out or which you were told came out of these crucibles?

A. No, sir.

192 Q. Did you ever see anything besides this which, to you best recollection, is in any way possibly connected with manufacturing carbons of any kind at Sawyer & Man's?

A. No, sir.

Counsel for complainant requests Examiner to note that Mr. Lowrey was again present at a portion of the afternoon session.

Adjourned to Friday, March 1st, at 11 A. M.

Friday, March 1st, 1889.

Met pursuant to adjournment.

Present—

R. N. Dyer, Esq., and Walter K. Griffin, Esq., for Defendants, and Thomas B. Kerr Esq., and Amos Broadnax, Esq., for Complainant, and Mr. Albon Man,

and the examination of Mr. Sharp was continued as follows:

R. N. Dyer and Walter K. Griffin, Esqs., as counsel for the defendants in the suit in the Southern District of New York, between the complainant herein and the Edison Electric Light Co. and Thomas A. Edison, request of record that the testimony taken for defendant in this present suit may be used by defendants in the New York suit upon the filing of copies certified by the Special Examiner herein, and as heretofore stipulated, in regard to the deposition of J. M. D. Keating, for the purpose of saving the retaking of such testimony, and further request the counsel for complainant present for an answer of record to such request.

193 Q. Do you know for what purpose the crucibles were used?

A. No, sir; I don't know really what they was used for.

194 Q. Was Mr. Myers at work with Sawyer & Man when you first went to Walker street?

A. That I can't say for certain whether he was there when I went there or not.

195 Q. How many men were employed in Sawyer & Man's at Walker street; name them?

A. Mr. Wm. Sawyer, George Sawyer, myself and Mr. Myers.

196 Q. How many men were employed at Howard street; name them?

A. Two, William Sawyer and myself.

197 Q. Did you see George Sawyer at Howard street?

A. I don't remember distinctly whether I saw him there or not.

198 Q. Did William E. Sawyer work at Walker street; if so what did you see him do?

A. Saw him treating carbons, making drawings and writing.

199 Q. Did he work at the bench?

A. I don't remember seeing him.

200 Q. Do you remember seeing him do any work at Howard street?

A. No, sir.

201 Q. When you were at Ansonia with William E. Sawyer what class of work was done there?

A. The class of work done in Ansonia was feeder lamps.

202 Q. What kind of a lamp was the feeder lamp?

A. The feeder lamp was a lamp with a long pencil, made by reversing the current to feed the lamp into contact in case it burnt out or got broke away in any way.

203 Q. How long would a feeder lamp burn?

A. I don't remember seeing it ever burn more than half an hour.

204 Q. What kind of carbon was used in the feeder lamp?

A. A long, thin hard carbon.

205 Q. Was it the same or different from the carbon used in the lamps at Sawyer & Man's?

A. As far as I knew it was the same kind.

206 Q. Outside of the carbon, please describe generally the lamps used by Sawyer & Man?

A. The lamps generally were a disc of metal with two upright posts. I don't know how to explain that; there was one with a kind of a bend, an L; the carbons were clamped between these two posts; the whole thing was supported by a zigzag strip of metal; this was all encased in a glass tube.

207 Q. Were the zigzag strips of metal all of the same shape in the different lamps?

A. They were, as a general thing.

208 Q. I show you a copy of the specifications of Letters Patent 205,144 to W. E. Sawyer and A. Man, dated June 18th, 1878, and ask you to look at the figure 1 in the drawings and state how that compares with the general style of lamp used by Sawyer & Man?

A. I remember that lamp, but I think that is the lamp that was made before the one I speak of, yet I could not say for certain whether it was one made before or after the ones I speak of. I remember having tubes in the latter ones to charge them with.

209 Q. I ask you to look at Figure 49 on page 83 of a book marked for identification "Sawyer's Book on Electric Lighting," March 1st, 1889, and to state whether you saw any lamp at Sawyer & Man's resembling such figure?

A. Yes, sir.

210 Q. When?

A. I think, when I come to think of it, that that was the lamp that was made before the feeder lamp.

211 Q. Was this early or late in the time you were at Walker street?

A. It was late.

212 Q. Please look at Figure 50, on page 85 of the same book, and state whether you recognize that figure?

A. Yes, sir; that is the general lamp that I spoke of.

213 Q. Please look at Figure 51, on the same page of the same book, and state whether you recognize that figure?

A. Yes, sir; that is the latest one; the other one I am mistaken in.

214 Q. Which one were you mistaken in?

A. I am mistaken in the one 49, the figure 49.

215 Q. What mistake did you make about that figure 49?

A. I haven't any distinct recollection of that lamp;

I think it is one that was made before my time.

216 Q. Look at Figure 52, on page 87 of the same book, and state whether you recognize that figure?

A. Yes, I recognize that.

217 Q. Where did you see anything resembling that, and what was it you saw?

A. That is the lamp I have described as having two upright posts with flat carbon clamps screwed together with platinum screws and nuts.

218 Q. Do you recognize the carbon in that figure?

A. I don't recognize the carbon as being as large as that.

219 Q. Do you mean as large as shown in the figure?

A. As large as shown in the semi-circle—the semi-circle in the figure.

220 Q. Were the posts or uprights for the carbon as far apart in the actual lamp you saw as in the figure?

A. I believe not.

221 Q. How many lamps did you ever see at Sawyer & Man's with the upright posts as shown in or as resembling figure 52?

A. One.

222 Q. Did you ever see any of the lamps resembling figures 49 or 50 or 51 altered over so that the posts in any way resembled figure 52?

A. Well, I can't say whether that one was altered over or whether it was made new.

223 Q. What kind of carbon did you see in the lamp resembling figure 52?

A. I saw retort carbon.

224 Q. How did it compare with the circles or half circles of retort you yourself made?

A. It appears to be about twice the diameter in the figure.

225 Q. What I mean is, was there any difference between the half-circles that you made and the circular carbon you actually saw in the one lamp at Sawyer & Man's resembling figure 52?

A. The only difference I see is that the carbons that I turned was an equal thickness all around, and equal breadth.

226 Q. You saw a lamp at Sawyer & Man's with circular carbons you say; were the circular carbons in that lamp the same or different from the half-circles of carbon you yourself made?

A. The one I saw there was the one I made.

227 Q. Look at the figure 55 on page 89 of the Sawyer book and state whether you recognize that figure?

A. Yes, sir; I do.

228 Q. How do you recognize it, and what does it resemble?

A. By its general appearance.

229 Q. What does figure 55 look like?

A. That is the feeder lamp. I made that all myself —all the parts.

230 Q. Where did you make it?

A. I think I made about two of them in Walker street --Walker and Elm.

231 Q. Did you make any more?

A. I don't know that I made any more there.

232 Q. Did you make any more elsewhere?

A. No, sir; but the parts of one hundred.

233 Q. Where did you make these parts of one hundred feeder lamps?

A. At Wallace & Sons, Ansonia, Conn.

234 Q. Was this while Mr. Sawyer was there?

A. Yes; they were started while he was there.

235 Q. You stated that you made two of these lamps at Walker street but only made the parts of the one hundred lamps at Ansonia. What is the difference in your mind between making a lamp and making the parts?

A. I made the lamp and put it together, all but the carbons, I believe, and in Ansonia the metal parts were made by different men.

236 Q. Do you recognize figure 54 in the Sawyer book?

A. That appears to me about the same thing, there is a little difference there. I can't; I don't know whether there is any difference or not. It looks to me as if this feeder tube in the figure was a little different, otherwise I don't see but what it is the same one.

237 Q. The same one as what?

A. 55.

238 Q. Do you recognize figure 53 in the Sawyer book?

A. No, sir; I can't say that I do.

239 Q. You have given the names of the workmen at Sawyer & Man's. Besides these men and besides what Mr. W. E. Sawyer or Mr. Man may have done, did you know of any one making carbons or doing work on carbons for Sawyer & Man, either at Howard street, or at Walker and Elm?

A. Only Mr. Myers.

Adjourned one hour for luncheon, to resume at 1¾ P. M.

Resumed at 1¾ P. M.

240 Q. You have spoken of refilling the lamps at Sawyer & Man's when the carbon burned out; what would you have to do to the lamps before they were ready for relighting?

A. Take them all apart, clean the parts, put new carbons in and sodium we used to put in a little in a piece of rag or cloth.

241 Q. Were the lamps recharged with gas?

A. Yes, sir.

242 Q. How long would this all take for one lamp?

A. About two or two and a half hours.

243 Q. Where was this work done, in the office or the workshop, or where?

A. It was done in the workshop.

244 Q. Were there any tools or apparatus in the office for this kind of work?

A. No, sir.

245 Q. Where were all the lamps refilled with gas that you saw refilled?

A. All in the workshop.

246 Q. What part of the shop?

A. On Mr. Myers' bench.

247 Q. Where were the carbons treated?

A. They were treated on the same bench.

248 Q. What different substances have you seen them treat the carbons in?

A. I can't remember now what substances they did treat them in. It was generally oil.

249 Q. Look at figure 41 on page 71 of the Sawyer book and state how that figure compares with what you remember as to the apparatus used for treating the carbons?

A. I don't remember seeing the apparatus at all.

250 Q. How did they fix the carbons for treating?

A. They used to have two metal rods in the bottom of an old lamp, and place a carbon in one end, the upper end of it, and place the electric wires on the other and immerse the carbon end in the oil. That is about all, I believe. They used electricity.

251 Q. How often would the lamps be taken apart and refilled?

A. I couldn't say how often—just as soon as they would be burned out or used up.

252 Q. Did you see this refilling done frequently or seldom?

A. I used to see it about every time.

253 Q. Who used to take the lamps apart and refill and refit them?

A. Mr. Sawyer and myself used to take them apart and refit them. Mr. Edward Myers used to do the filling. Sometimes it was done outside at Mr. Stillman's down in Broadway.

254 Q. Do you mean the refilling or the refitting?

A. Refilling.

255 Q. When a lamp was completed was it kept in the same shape or altered?

A. Well, sometimes altered, sometimes kept in the same shape.

256 Q. What alterations were they making?

A. I don't know. They might make some little difference in the shape of the carbon holders, or some little thing of that kind.

257 Q. How often would such little alterations be made in the lamps ?

A. They would be making them pretty much all the time.

258 Q. How many years have you been a mechanic, and what trade did you learn ?

A. I have been working as journeyman mechanic about thirty to thirty-five years. I learned the trade of general brass finisher.

259 Q. Did you ever know of a lamp at Sawyer & Man's which you were told by any one or which, in your judgment, was a satisfactory lamp as an electric lamp ?

Objected to as incompetent.

A. Well, I can't tell exactly whether any one has told me that they had such a lamp, but I never considered that there was one.

260 Q. What did you consider the lamps ?

Same objection.

A. I didn't consider the lamps anything more than an experiment.

261 Q. You mentioned making the parts of a hundred lamps at Wallace's. How many of these were put together, so far as you knew ?

A. Well, not more than ten or twenty, at the very outside.

262 Q. What became of the lamps, so far as you know ?

A. The last I saw of the lamps they were cleaning out the room and fired the lamps all out in the yard ?

263 Q. Who fired them out ?

A. William Wallace, Junior, I believe.

264 Q. Have you ever testified as a witness before ?

A. I testified a little for a man in Brooklyn about building a house.

265 Q. Is that your only experience as a witness ?

A. No, sir ; that's all.

Cross-examination by Mr. Kerr :

266 x-Q. How long have you been acquainted with Mr. Albon Man ?

A. I should think about fifteen or sixteen years.

267 x-Q. Have you known him intimately ?

A. Only through business.

268 x-Q. Do you believe him to be a man of truth and veracity.

Objected to as irrelevant and immaterial.

A. I do, so far as I have known him and heard of him.

269 Q. Do you think that Mr. Man would, when testifying under oath, testify to a falsehood ?

Same objection.

A. I should not think he would.

270 x-Q. If Mr. Man should make a statement to you in regard to something which he said he did or had seen, would you believe him ?

Same objection.

A. Of course, I suppose I should have to if I did not know any different.

271 x-Q. On March 14th, 1881, Albon Man testified in an interference case in the U. S. Patent Office, between Sawyer & Man and Thomas A. Edison, as follows :

"Early in the month of October, 1878, we prepared paper carbons in the manner I have described, by carbonization, in the furnace at the corner of Elm and Walker streets, in this city, and perfected them substantially as I have described, and used them during the month of October and the following month, until the latter part of March, 1879, in electric lamps at that place, successfully, and exhibited them to great numbers of people."

Do you believe that Mr. Man was swearing to a falsehood when he gave that testimony?

> Objected to as incompetent, immaterial and irrelevant and improper, especially because Mr. Man has not testified in this present suit, and because complainant's counsel, General Duncan, in open court, at Pittsburgh, made the statement to the effect that one of the objects of the form of the bill of complaint herein was to avoid the necessity of putting Albon Man on the stand on direct, and as an improper attempt to introduce alleged testimony in this suit.

A. Well, I can't say anything about that, but I can say that I have never seen or heard anything of paper carbons until a year or two after April—May—a year or two after May, 1879.

272 x-Q. That is no answer to my question. Please answer my question?

A. That is a question I would not like to answer. I have not had sufficient dealings with Mr. Man to know for certain what he would do.

273 x-Q. The question has nothing to do with your knowledge. I want you to say whether or not you believe that Mr. Man, when he gave that testimony, was swearing to a falsehood?

> Same objection.

A. I tell you I don't know. I couldn't say for certain. The thing is, I haven't seen it. I haven't seen it in use nor heard of it.

274 x-Q. My question has nothing to do with your seeing or hearing of it. I want you to tell me whether you believe that Albon Man was swearing to a falsehood when he gave that testimony?

> Same objection, and as especially incompetent in view of the witness' answers.

A. That is something I don't care to answer.

275 x-Q. I insist on an answer?

> Same objection, and further, because complainant has no right to cross-examine the witness except as to facts and circumstances connected with the examination on direct. Defendant's counsel instructs the witness not to answer the question.

A. Under advice of counsel I so refuse.

276 x-Q. When you came here to give your testimony did you know about the testimony of Mr. Man as to the manufacture and use of lamps with paper carbons at Walker and Elm streets?

> Objected to as immaterial and irrelevant, and beause there is no testimony of Mr. Man in this case, and for the further reasons stated to cross-questions 271 to 275, inclusive.

A. No, sir.

277 x-Q. Were you told that he had testified to any such facts?

> Same objections.

A. No, sir.

178 x-Q. How did you happen to come here to testify?

A. I was hunted up and brought here, or invited here.

279 x-Q. Well, which?

A. Invited.

280 x-Q. Who by?

A. By Mr. Russell.

281 x-Q. Who is he?

A. Mr. Russell is a gentleman I see around here. I don't know any more than that. He must be a kind of an agent.

282 x-Q. Around where?

A. Around this office.

283 x-Q. When did Mr. Russell first see you about testifying?

A. About two years and a half ago.

284 x-Q. Can you fix that date exactly?

A. No, sir.

285 x-Q. Why not?

A. Because I don't know it.

286 x-Q. Where did you see Mr. Russell first?

A. In the office of the Ansonia Brass and Copper Company, Ansonia, Conn.

287 x-Q. Were you working there?

A. No, sir.

288 x-Q. How did he happen to find you there?

A. By inquiry, I suppose. I don't know how he found me there.

289 x-Q. Did he tell you who gave him your address?

A. I can't say for certain, but I believe he said that George Sawyer told him I was working at Wallace's.

290 x-Q. Well, what did he say to you when he saw you?

A. That I can't tell you now; it is too long ago. He told me that Mr. Tomlinson would like to see me, something on my old—— well, I can't tell now what he did say, really. He wished me to come down and see Mr. Tomlinson.

291 x-Q. Didn't he ask you anything about what you would testify to?

A. He asked me if would testify about the lamps and what I was working on—that is, after I got down to the office here.

292 x-Q. Did you come down with Russell from Ansonia to New York?

A. No, sir; I did not.

293 x-Q. When did you come down?

A. I came down the next morning.

294 x-Q. According to your agreement with Russell?

A. Yes, sir.

295 x-Q. Did Russell give you any money?

A. He gave me enough to pay my expenses down.

296 x-Q. How long were you in New York at that time?

A. I don't know whether I went back the same night or the morning following. It might have been the next night.

297 x-Q. Where were you working at Ansonia?

A. At the Electrical Supply Co.

298 x-Q. Is that company still in operation?

A. For anything that I know, it is.

299 x-Q. Did it have a time-book showing the time of the men?

A. I don't know whether it had a time-book or not. It had a time list.

300 x-Q. Would you absence that day be shown by that time list?

A. I think very likely it would. It would on Saturday, I know—or Thursday, rather, pay day.

301 x-Q. Were you absent often from work?

A. No, sir; very seldom.

302 x-Q. Fix the month and year, if you can, when you came to New York at that time?

A. I can't do it very well. It might be somewhere in June, about 1888, I think so; 1887 I meant to say.

303 x-Q. Do you think it was that time?

A. I think it was somewhere about that time.

304 x-Q. That would be less than two years ago?

A. Then that can't be the time; it was about two years and a half ago.

305 x-Q. Why do you think it was two years and a half ago?

A. Because it was about a year and a half before I left Ansonia, and I have been in New York a little over a year.

306 x-Q. When you came to New York on that trip whom did you see?

A. I saw Mr. Russell. He introduced me to Mr. Tomlinson.

307 x-Q. Where did you see Russell?

A. Right out here on the landing. In this hallway here.

308 x-Q. Did you at any time make any statement or affidavit?

A. I made a statement.

309 x-Q. Was it taken down in writing, and if so, by whom?

A. It was take down in short hand writing by some stenographer.

Defendant's counsel offers said statement for the inspection and use of complainant as they may deem proper.

Same placed on the table in front of counsel for complainant by counsel for defendant.

310 x-Q. To whom did you make the statement?

A. Mr. Tomlinson.

311 x-Q. Was it read to you after you had made it?

A. Yes, sir.

312 x-Q. How long did you wait for it to be written out?

A. I couldn't say how long it was, perhaps half an hour or an hour.

313 x-Q. Did you read it yourself?

A. No, sir.

314 x-Q. When was it read to you?

A. It was read to me as soon as it was written, as near as I can remember.

315 x-Q. When did you next hear of that statement?

A. About two or three hours afterwards, after it was put in printed form.

316 x-Q. How did you hear about it then?

A. The stenographer brought it back here and read it over again.

317 x-Q. Did you sign it?

A. That I can't say now whether I did or not. I think likely I did.

318 x-Q. Was it dated?

A. I suppose so.

319 x-Q. Did you receive a copy of it?

A. No, sir; no further than to see it brought back in the office and read over.

320 x-Q. When did you next hear of that statement.

A. I didn't hear anything more of it since then.

321 x-Q. Did you swear to that statement when you made it?

A. I don't remember now whether I did or not.

322 x-Q. Did you swear to the copy of it after it was typewritten?

A. That is a rather funny thing for me to swear to.

323 x-Q. What was funny about it, wasn't it true?

A. Well, if it was read over to me I might possibly swear to it, but to look at it I couldn't tell anything about it?

324 x-Q. Have you within the last few days had a paper read to you, and been told that that paper was a statement made by you when you were here the first time?

A. No, sir.

325 x-Q. Has such a paper been shown to you?

A. That is about the first time I have seen it, I believe.

Witness points to paper on the table.

326 x-Q. Do you mean to say that you have not seen that paper during the last week?

A. Yes, sir.

327 x-Q. Has any reference been made to a statement which you formerly made?

A. I don't remember of any.

328 x-Q. When were you requested to come here and testify?

A. This time or the time before?

329 x-Q. At this hearing?

A. Tuesday of this week, I believe.

330 x-Q. Who requested you to come?

A. Mr. Russell.

331 x-Q. When did you come?

A. Wednesday morning.

332 x-Q. Did Russell talk to you on Tuesday about your testimony?

A. Not as far as telling me anything about what was in it.

333 x-Q. In what?

A. In my testimony.

334 x-Q. What testimony do you refer to, the statement made two years and a half ago?

A. Yes, sir.

335 x-Q. Did Russell have a copy of that statement you made two years and a half ago along with him?

A. I don't know what he had with him. I didn't see any. I don't know that it was mentioned in any way.

336 x-Q. Was it mentioned on Wednesday?

A. I don't remember of its being mentioned.

337 x-Q. Did you see it on Wednesday?

A. I don't believe I did.

338 x-Q. Was any statement made to you on Wednesday as to what it contained?

A. No, sir.

339 x-Q. Did you see it on Thursday?

A. No, sir.

340 x-Q. Were you told what was in it on Thursday?

A. No, sir.

341 x-Q. Did you see a copy of it on Thursday?

A. No, sir.

342 x-Q. Do you mean to be understood that never since the time that you made the statement to Mr. Tomlinson two and a half years ago until the present, you have not seen or heard of that statement or had any information as to its contents to the present time?

A. I mean to say that I haven't seen or heard anything about it.

343 x-Q. Then you can't say that the paper, which was placed on this table by counsel, is the statement you made two years and a half ago, can you?

A. I can't. I haven't seen the inside of it yet. I can't tell anything about it.

At this point counsel for complainant take the paper and retire from the examination room.
Counsel return.

344 x-Q. Please read the paper which counsel placed on the table, and state whether that is the statement made by you to Mr. Tomlinson, about which you have been testifying, and whether it was signed and sworn to by you, and, if so, upon what date?

Paper handed to witness.

A. I am pretty satisfied that that is the statement. It was signed on the day I came down here. I can't make out what the figures are. It looks like the 12th day of June, 1886. Well, I can't say, really, as to swearing, except as it is here.

Defendant's counsel (Mr. Kerr and Mr. Broadnax being present) read and repeat the request already of record, as to the books and papers of the Electro-Dynamic Light Co.

Complainant's counsel suggests that no foundation has been laid for any such request or any reasons stated, nor the materiality of said books and papers shown, in any way, nor does the request seem to have reason about it that commends it to plaintiff's counsel. Complainant's counsel further suggest that this is not a dragnet investigation, and that there is a proper and legal way which defendant can adopt to obtain anything that it is entitled to obtain. Furthermore, complainant's counsel state that they have not got such books and papers in their possession, and don't know where they are.

Complainant's counsel also asks Examiner to note that G. P. Lowrey, Esq., was present for a part of the time, during the morning session.

Adjourned till Saturday the 2d inst., at 10:30 A. M.

New York, March 2, 1889.

Met pursuant to adjournment.

Present—Mr. Dyer for defendant, and Mr. Broadnax for complainant; and the examination proceeded.
Also present—Mr. Man.

Cross-questions by Mr. Broadnax:

345 x-Q. Please to make a pen and ink sketch of the first lamp you made for Sawyer & Man, or for either of them?
A. I don't know that I can just get on to the first one I had to do with.
346 x-Q. Make it nearly as you can recollect?

Witness makes a sketch and produces the same.

A. That is as near as I can remember it.
347 x-Q. Referring now to the sketch made and produced by you, what does the part marked A represent?
A. The glass globe.
348 x-Q. What does the part B represent?
A. That represents an upright, to hold the top piece E?
349 x-Q. You mean one end of the top piece E?
A. I am not sure whether that piece rested on one end or the centre.
350 x-Q. I do not understand your last answer. Please to state what you mean?
A. What I mean is that I don't know whether this top piece E was pivoted at the centre of the top piece or the left end of the top piece.
351 x-Q. What does the part D represent?
A. D represents a wire drawing E, to bind carbon F on upright post C.
352 x-Q. What does the part C represent?
A. I should call that the upright C, holder for the carbon.

353 x-Q. What does the part I represent?
A. The part I represents the bottom part of the globe.
354 x-Q. What do the parts H H represent?
A. The parts H H represent coming through two holes in the bottom of the glass to hold up the upright.
355 x-Q. Do you mean that the parts H H represent the bottom ends of the upright B and C where they passed through the bottom of the lamp and where they are sealed therein?
A. Yes, sir.
356 x-Q. Was the bottom of the lamp made of glass?
A. A and I are all one continuous piece of glass.
357 x-Q. Then the bottom of the lamp was not made of a separate disc of glass, as I understand you?
A. No, sir; it was all one piece.
358 x-Q. Now were the uprights B and C tubular; I mean were they made of small tubes?
A. I can't say really what they were made—whether of tubes, strips of metal or what. They were metal.
359 x-Q. Was the upper end of the part B made wedge-shaped as you have shown?
A. I think it was.
360 x-Q. What does the part F respresent?
A. The part F represents the pencil of carbon.
361 x-Q. And the part E, what does that represent?
A. The part E represents a piece of metal bearing on one end of the carbon, and pressing the carbon on the upright C.
362 x-Q. And the other end of the part E, as I understand you, bears upon the top of the part B?
A. Yes, sir.
363 x-Q. The part E is held down on the parts F and B by the part D?
A. Yes, sir.
364 x-Q. Now did the lower end of the part D pass through the bottom of the lamp, about midway between B and C?
A. That I can't remember about. The wire came

through somewhere, but where I don't recollect; somewhere on the bottom.

365 x-Q. By the wire you mean the part D?

A. Yes, sir.

366 x-Q. Now, wasn't the part D secured to the loop at its lower end, which was fastened to the inside of the bottom of the lamp?

A. I couldn't say. I don't remember it.

367 x-Q. Did the whole or any part of the part D consist of a small spiral spring?

A. I couldn't remember; but it seems to me there was a small spiral spring attached to it.

368 x-Q. There must have been some way of drawing or holding the part E down upon the upper ends of E and B. Can't you call to mind how that was done?

A. No, sir; I cannot.

369 x-Q. Were the lower ends of the parts B and C sealed in the bottom of the lamp?

A. They were.

370 x-Q. How were they sealed?

A. Those bottom pieces H H, were turned with a flange partly conical shape under the flange, the lower part straight with a thread. They are cut in two halves, slipped inside of the glass, with a paper washer, I believe. The two halves were drawn through the paper as a washer, then through the glass, another paper washer on the outside of the glass, and screwed down with a nut.

371 x-Q. Please to make a sketch of the arrangement you have described in your last answer?

Witness makes and produces a sketch.

A. I have done so.

372 x-Q. Is this sketch marked Figure 2 which you have just produced the best you can recollect of the method of fixing and sealing the lower ends of the parts B and C in the bottom of the lamp?

A. Yes, sir.

373 x-Q. And in this sketch, Figure 2, as I understand it, there is a vertical section of a conical tubular end shown, into which or to which the parts B and C are connected; the nut M, shown in Figure 2, being screwed on the lower end of the part K, the part K being made in two parts, joining in the centre vertically. Is that the way it was?

A. That is as near as I can think of it.

374 x-Q. Now, can you recollect how the lower ends of the parts B and C were connected to the parts K K?

A. No; I can't remember just how it was done.

375 x-Q. Did the parts K K, when they were put together, form a tube or hole through the centre?

A. I don't know whether it formed a hole or not, but I know that it clamped the two uprights.

376 x-Q. Now, how was the carbon F fixed in the upper end of the part C?

A. I don't remember whether there was a countersink in the top of upright C or what there was.

377 x-Q. In short, you don't recollect how part F and part C were united, as I understand you?

A. All I remember is that they were put in between these two points and held down by the wire or spring D.

378 x-Q. What were the uprights B and C made of?

A. That I can't tell; there was a piece of metal, but what the form of the metal was is more than I can tell.

379 x-Q. What was the part F made of; was that made of metal also?

A. The part F is supposed to be made of carbon.

380 x-Q. Do you distinctly recollect that that part was made of carbon?

A. No, sir; I do not.

381 x-Q. Did you understand this lamp to be an incandescent electric lamp?

A. No, sir; I didn't know anything at all about it, what it was.

382 x-Q. Who told you to make it?

A. Mr. Man and myself made it together, or rather I worked according to Mr. Man's dictation.

383 x-Q. Did you make this lamp at your house?

A. Yes, sir.

384 x-Q. What did you understand it to be for when you made it?

A. I didn't know anything at all about it; Mr. Man got me to make such parts as he wanted, and I made them as directed.

385 x-Q. Did you see it after it was finished?

A. Mr. Man and I put the parts through into the lamp; made the connections in the bottom; whether we put a carbon in or not, I can't say for certain. Then Mr. Man took it away with him, and that was the last I heard of it.

386 x-Q. Did not Mr. Man tell you what it was for.

A. He did not.

387 x-Q. Then, as I understand you, you made this lamp without having any idea what it was for?

A. Yes, sir.

388 x-Q. Did you subsequently ascertain what it was for?

A. I don't believe—I don't know that I ever saw or heard anything of it afterwards.

389 x-Q. Who made the holes in the bottom of the lamp into which the uprights are set or secured?

A. Those was made in the glass when I got it.

390 x-Q. Did you not drill these holes yourself with a steel drill?

A. If I am not very much mistaken they were punched out in the glass-house wherever the glass was made.

391 x-Q. Do you mean to answer my question in the negative?

A. I don't remember of doing so.

392 x-Q. As I understand, you cannot swear that you did nor can you swear that you did not drill these holes in the bottom of this lamp. Is that correct?

A. I cannot swear either way.

393 x-Q. In placing these uprights in the bottom of the lamp, did you use cement or any other material for the purpose of making an air-tight joint between the uprights and the glass bottom?

A. I don't remember making anything more than paper washers. If I remember right my thought was to keep from breaking the glass.

94 x-Q. Did Mr. Man tell you that he wanted those uprights made with an air-tight joint between them and the glass?

A. Not that I can remember.

395 x-Q. Do you remember of drilling holes in a lot of glass discs which were to form the bottom of incandescent electric lamps at your house?

A. I remember drilling holes in such things, whether I drilled any of them at my house or not I don't remember. I believe I drilled some corner of Walker and Elm streets.

396 x-Q. How did you drill those holes?

A. As near as I can remember I drilled them with a hand drill and turpentine.

397 x-Q. What was the drill made of?

A. Steel with a very hard point.

398 x-Q. Now, this, as I understand you, is the first lamp that you made at your house for Mr. Man?

A. According to my recollection, I believe that was the first one.

399 x-Q. Did Mr. Sawyer see you at all in connection with this lamp; in connection with the making of this lamp, I mean?

A. No, sir; he did not.

400 x-Q. Did you make two lamps at your house for Mr. Man?

A. I believe I made one more after that.

401 x-Q. Please to make a pen and ink sketch of the second lamp made by you for Mr. Man at your house?

A. I can form very little idea of the second lamp I made, any further than that it was in tubular form.

402 x-Q. Please to illustrate it in a sketch as far as you recollect it?

Witness makes and produces a sketch as requested.

403 x-Q. Referring to the sketch you have just made, what is represented by the part A of that sketch?

A. The part A is a glass tube with a flange at B.

404 x-Q. The part C: what does that represent?

A. That represents the bottom of the tube A.

405 x-Q. In this case, as I understand you, the enclosing globe of the lamp is represented by A, and that this globe has an open bottom which was closed by a separate disc of glass C. Is that the way it was?

A. I can't remember whether the disc C was made of glass, metal or soapstone.

406 x-Q. And yet you say you made the lamp?

A. Yes, sir.

407 x-Q. Were there holes in the disc of the lamp that formed the bottom?

A. I believe there were.

408 x-Q. Please to put them in your sketch.

A. I do so and letter them D D.

409 x-Q. What were these holes for that you have illustrated and marked D D?

A. They were to—I don't know hardly how to explain that—they must be for the holders of the carbon.

410 x-Q. Well, they were as a matter of fact, holders for the carbon, were they not?

A. So far as I know about lamps now, they must be—they were.

411 x-Q. Please to illustrate them on the drawing as nearly as you can—I mean the carbon holders to which you have referred?

A. I can't illustrate them because I can't form any idea what they are.

Adjourned for lunch.

Resumed after lunch.

412 x-Q. Do you mean that you have so far forgotten the construction of the lamp as to be unable to illustrate its principal parts?

A. I do.

413 x-Q. And that you have illustrated it as far as you are able to?

A. Yes, sir.

414 x-Q. Now, did you see either of the lamps of which you have made sketches in part illuminated?

A. I did, sir.

415 x-Q. I am referring, of course, to the identical lamps that you made. Did you understand me in that way?

A. Yes, sir.

416 x-Q. Which one of the lamps did you see illuminated?

A. Figure No. 3.

417 x-Q. Did you put the carbon in that lamp?

A. No, sir; I did not.

418 x-Q. Do you know who did?

A. No, sir.

419 x-Q. For whom did you make that lamp?

A. For Mr. Man.

420 x-Q. Did Mr. Sawyer give you any direction in the construction of that lamp?

A. No, sir.

421 x-Q. You made it, as I understand you, wholly under the direction of Mr. Man, and delivered it to him?

A. I did, sir.

422 x-Q. Where did you see it illuminated?

A. Mr. Sawyer turned it on for me soon after I went to work at the corner of Centre and Howard streets.

423 x-Q. What did Sawyer "turn on"?

A. Turned on the current of electricity.

424 x-Q. How long was that after you delivered the lamp to Mr. Man?

A. It might be a month, it might be two months after.

425 x-Q. How do you know that it was a month or two months?

A. Well, I don't know for a certainty. I am only giving it to you as near as I can think of it.

426 x-Q. Can you give the time when you went into the employ of Messrs. Sawyer & Man at their shop or laboratory?

A. No, sir; I cannot. I have no recollection of the dates.

427 x-Q. Can you tell about how long it was after you went into the employ of Messrs. Sawyer & Man at their shop before Mr. Sawyer turned the current into the lamp for you?

A. No, sir; I cannot. I can't give it any nearer than I gave it before.

428 x-Q. Then, I understand you to say that your best recollection is that it was within one or two months after you delivered to the lamp to Mr. Man you saw that same lamp illuminated?

A. Yes, sir.

429 x-Q. Can you recollect when it was that you delivered the lamp to Mr. Man?

A. All that I can say on that is that when the lamp was finished Mr. Man took it away with him. I can't give any date; I can't remember any.

430 x-Q. State what year it was, and as near as you can what time in the year?

A. I don't know. I should think it must be somewhere in July of 1878.

431 x-Q. You are referring now to the lamp you saw illuminated, as I understand you?

A. I am referring, I believe, to the time I went to work for Sawyer & Man, if I understand it right.

432 x-Q. You misunderstand me; I am referring to the time when you delivered the last lamp you made to Mr. Man; give the year and the month in the year when that occurred?

A. I think it must have been somewhere about May or June of 1878.

433 x-Q. Is that as near as you can give the date?

A. It is.

434 x-Q. How do you know that the lamp Mr. Sawyer turned the current on for you, as you have testified, was the identical lamp you made for Mr. Man?

A. Mr. Sawyer told me that that was the lamp and the best lamp of any they had had. That is the first lamp that I know of being a lamp. I did not know that it was a lamp until I went to get my pay for it from Mr. Man. Then he called my attention to it and

said it was a very good lamp, and he thought that I might like to know what I had been working on.

435 x-Q. Was that before or after you had seen it illuminated?

A. It was before I saw it illuminated and within a few days after I delivered it to Mr. Man.

436 x-Q. When you say "lamp" in your previous answer you mean an incandescent electric lamp, do you?

A. I do, sir.

437 x-Q. When you saw this lamp illuminated by Mr. Sawyer, were you able to identify it as the lamp you had made, irrespective of anything Mr. Sawyer told you?

A. Well, I can't remember now; I believe I made a surprise at the time, and told Mr. Sawyer I wouldn't have known it.

438 x-Q. How long did you see the lamp illuminated?

A. A few seconds.

439 x-Q. When you say you saw it illuminated "a few seconds," do you mean that Mr. Sawyer then turned the current off from the lamp, or do you mean that the lamp went out on account of the disruption of some of its parts?

A. Mr. Sawyer turned the current off.

440 x-Q. At that time did you understand the principle or mode of operation of these lamps?

A. I did not.

441 x-Q. Do you understand the principle or mode of operation of the lamps now?

A. I don't understand very much about it any further than one pole has got to be insulated from the other.

442 x-Q. Is that all you know about it?

A. Perhaps I have stated that wrong; I ought to have said I believe that one pole should be insulated from any metallic parts of the works of the lamp, so that the two poles may work through.

443 x-Q. After you made the first lamp shown by your pen and ink sketches, Figures 1 and 2, how long

was it before you made the other one shown by Figure 3?

A. I don't know; I should suppose it would be, perhaps, a couple of weeks.

444 x-Q. Is that all the lamps you made for Mr. Man at your house?

A. That is all.

> The two pen and ink sketches made and produced by the witness, marked as Figures 1, 2 and 3, are offered in evidence as Complainant's Exhibits Sharp's Drawings, said exhibits being offered as part of the cross-examination of the witness Sharp, and the same are marked Complainant's Exhibits Sharp's Drawings, Figures 1, 2 and 3, March 2d, 1889.

445 x-Q. After you had delivered the lamps, about which you have been testifying, to Mr. Man, what is the next work you did for them or either of them?

A. I can't remember the class of work I did there.

446 x-Q. Did where?

A. At Centre and Howard streets.

447 x-Q. Was Centre and Howard streets the place where you did the first work for them or either of them after making and delivering the two lamps to Mr. Man about which you have been testifying?

A. It was.

448 x-Q. And, as I understand you, you do not recollect what the work was that you first did when you went in their employ at Centre and Howard streets?

A. That is right.

449 x-Q. What kind of work were you employed upon for them at Centre and Howard streets?

A. As near as I can tell, it was parts of electric lamps. When I first went there I didn't know anything about electricity. I was working with Mr. Sawyer, helping him out at whatever he was doing.

450 x-Q. Do you mean Mr. Wm. E. Sawyer?

A. No; I mean Mr. Wm. Sawyer.

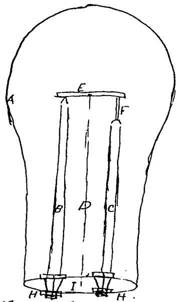


FIGURE I.

William Sharp

Complainant's Exhibit
Sharp Drawings.
Figs I and 2.
March 2d 1889
W.T.F.
S.E.

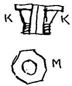


FIGURE 2.

Complainants Exhibit
Sharp Drawing
Fig. 3.
March 2d 1889
W J F
J. E.

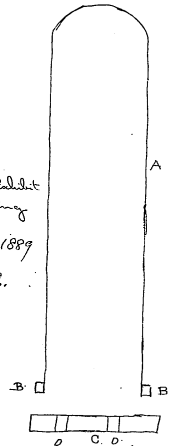


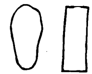
FIGURE 3.

William Sharp

451 x-Q. What was he doing that you helped him on?

A. The only thing I can distinctly remember is pieces of brass like the sketch which I now make on this sheet.

Witness makes the accompanying sketch.



452 x-Q. What are these sketches intended to represent? I mean, what were these pieces of brass for?

A. As far as my knowledge goes, they were parts of some of the lamps they were then making.

453 x-Q. Was it not explained to you what parts of the lamp these pieces of brass were intended for?

A. I don't know that it was. I supposed at the time that I was on lamp work.

454 x-Q. But really you didn't know whether you were or not?

A. I did not.

455 x-Q. How many of these pieces of brass did you make and how long were you to work upon them?

A. I have no recollection.

456 x-Q. What else did you work on besides these pieces of brass?

A. That was all I can recollect.

457 x-Q. Was this work done in the shop of Arnoux & Hochhausen?

A. It was.

458 x-Q. Under the direction of Mr. Wm. Sawyer, as I understand you?

A. Yes, sir.

459 x-Q. How much of your time at Howard and Centre streets was spent at work in the shop of Arnoux & Hochhausen, and how much of your time was spent downstairs in the room of Mr. Sawyer?

A. My time was all spent in the workshop of Arnoux & Hochhausen with the exception of a few minutes, perhaps two or three times.

460 x-Q. Now, when the shop or laboratory of Sawyer & Man was moved from Howard and Centre streets to the corner of Walker and Elm, did you go with them and continue right on in their employ?

A. I did not, not at first.

461 x-Q. How long after the removal to the corner of Walker and Elm before you went there to work for Sawyer & Man?

A. When Sawyer & Man moved I went to work for Arnoux & Hochhausen. Then they used to borrow me from Arnoux & Hochhausen about every day or every other day to do some job for them for perhaps two or three weeks. Then they took me to work for them altogether until Sawyer & Man disagreed and broke up the business.

462 x-Q. And that was when?

A. I can't give you any dates. I don't remember them.

463 x-Q. Now, during the time that Sawyer & Man were borrowing you of Arnoux & Hochhausen, how much of your time was spent in the laboratory of Sawyer & Man after their removal to Walker and Elm streets?

A. I don't know. I might, perhaps, have been there one, two or three days in the week.

464 x-Q. What work was you engaged upon for them during that time?

A. That I don't remember.

465 x-Q. After you left Arnoux & Hochhausen's employ and went into the employment of Sawyer & Man, what work were you engaged upon for them. I mean when you first went in their employ there?

A. It was work similar to what I have been working on all the way through, experimental work, such as making parts for experimental lamps.

466 x-Q, What were the first experiments or parts for experimental lamps that you worked on after going to work in that shop?

A. I couldn't tell you no more than if I had never made them.

Adjourned till Monday, the 4th inst., at 10½ A. M.

MONDAY, March 4th, 1889.

Met pursuant to adjournment.

Present—MR. GRIFFIN for defendants, MR. KERR for complainant, and MR. ALBON MAN and the cross-examination of MR. SHARP was continued.

QUESTIONS BY MR. KERR:

467 x-Q. Did you ever assemble any lamps for Sawyer & Man?

A. Do you mean by "assembling" putting them together?

468 x-Q. Yes.

A. Yes, sir.

469 x-Q. Those lamps all had a base plate, did they not?

A. Are you referring to No. 3 now?

470 x-Q. No, I am not referring to No. 3.

A. All but the first one I made.

471 x-Q. And the working parts were all mounted on that base plate, weren't they?

A. Yes, sir.

472 x-Q. Then when the lamp was put together the working parts were inserted into the glass globe, and the base plate was clamped to the lower open end of the glass globe?

A. Yes, sir.

473 x-Q. How was it clamped?

A. They were clamped by two rings—one above the flange of the glass globe, one under the base and clamped together with about six screws, as near as I can think.

474 x-Q. When you wanted to take out the working parts what did you do?

A. We had to take the screws out, and take the rings off and take the works all out with the base.

475 x-Q. Merely pull them out?

A. Yes, sir.

476 x-Q. How long did it take you to undo the six screws?

A. It might take about two or three minutes.

477 x-Q. Then how long did it take to pull off the rings and pull the base plate off the lamp?

A. About one minute, I guess.

478 x-Q. Wasn't that a long while for that operation?

A. Sometimes it was not.

479 x-Q. Why not?

A. Sometimes we would have to warm the bottoms of the lamps to get them apart—soften the cement.

480 x-Q. Did you ever have to pry the base plate off?

A. Not very hard.

481 x-Q. How long did it take you to wipe out the globe?

A. I don't remember whether I wiped out the globes or not. I might have done it sometimes.

482 x-Q. Did you ever put in a new carbon in the clamps?

A. That is something I can't distinctly remember.

483 x-Q. Did you ever see it done?

A. Yes, I believe I have seen it done.

484 x-Q. Where there were screws to clamp the carbons, how long did it take to take out an old one and put in a new one and screw up the clamping screws?

A. That is something I can't give just exactly; I should think on an average it might take a couple of hours.

485 x-Q. A couple of hours to unscrew two screws, take out a little piece of carbon less than an inch long from the loose clamps, and then put in another piece into the open clamps and screw up two clamping screws again. Do you mean that?

A. In taking down a lamp there was always more or less cleaning to be done, and instead of two clamping screws there were six.

486 x-Q. Six clamping screws to hold the carbon in the carbon clamps—do you mean that?

A. No, sir; I mean putting the lamp together, all through.

487 x-Q. I didn't say anything about cleaning or putting the lamp together all through. Now please go back to question 485 and answer it?

A. No, sir; that wasn't my general work, putting in the carbons.

488 x-Q. That don't answer my question. How long would it take to unscrew the two clamping screws which held the carbon?

A. I don't know whether two clamping screws come in on the carbon.

489 x-Q. How was the carbon held?

A. As near as I can think of it, it was done with a small wire and a spiral spring, with a short piece of threaded wire and one nut to regulate it.

490 x-Q. How long would it take to take a broken carbon out of that kind of a fastening?

A. They would generally fall out themselves, break and fall out.

491 x-Q. Then how long would it take you to put a new carbon back into those fastening devices?

A. Without cleaning it would take about a couple of minutes.

492 x-Q. Then after you had the carbon in the clamp and the globe cleaned you put the lamp together by inserting the works inside of the globe, putting on the two clamping rings at the bottom and screwing up the six screws in the clamping rings, did you not?

A. I did.

493 x-Q. How long did that take you?

A. Before doing that we had to cement the two glasses with Canada balsam. I had to be very careful not to get the balsam smeared on the inside and for that reason and being careful not to break the glass by tightening one screw tighter than another it would take fifteen or twenty minutes.

494 x-Q. Did you put the balsam on the base plate or on the end of the globe?

A. I suppose I put it on the end of the globe. That would be the most proper place.

495 x-Q. You simply touched the end of the globe with a brush dipped in the balsam, did you not?

A. I don't know whether it would be wood or whether it was wire. I had no brush.

496 x-Q. How much of the fifteen or twenty minutes did it take you to put the balsam on the end of the globe?

A. It might take two or three minutes to put it on the globe and work it evenly through, leaving no air space.

497 x-Q. Then it took you from twelve to seventeen minutes to put in the six screws?

A. That is the figures as near as I can give them to you. I never timed myself on any of the work.

498 x-Q. Don't you think that you have given four or five times too much time to that operation of putting in six screws?

A. I don't think I have given any too much time for taking it altogether.

499 x-Q. I am not taking it altogether. I am taking the six screws by themselves?

A. I don't think I have given much over the time that it would take.

500 x-Q. Isn't it a fact that this work was done by Mr. Myers and not by yourself as a usual thing?

A. As a usual thing it was done by myself.

501 x-Q. How often did you do it altogether?

A. I can't say. I don't remember.

502 x-Q. Ten times?

A. Yes.

503 x-Q. More than that?

A. Yes, sir.

504 x-Q. Twenty times?

A. Yes, over fifty times.

505 x-Q. How much over fifty times?

A. I don't know; I wouldn't want to go any further than that.

506 x-Q. Are you willing to swear that you did it more than fifty times?

A. I have no recollection of the number of times I have taken. I can't swear to a thing that I don't remember perfectly.

507 x-Q. What is your impression?

A. I haven't got any.

508 x-Q. Then you are not willing to swear that you did it more than fifty times?

A. No, sir.

509 x-Q. Did Myers ever change any carbons?

A. I think Myers was the man that generally done it —Mr. Edward Myers.

510 x-Q. The only other thing necessary in changing the carbons was to exhaust and fill the lamps—is that so?

A. Yes, sir—well, I don't know; there was sealing after that.

511 x-Q. Who did that work of exhausting, filling and sealing?

A. I have seen Edward Sawyer do it, Edward Myers and Thomas Stillman.

512 x-Q. Where did they do it?

A. They did it on Mr. Myers' bench.

513 x-Q. What kind of apparatus did they have for exhausting the lamp?

A. The first thing I saw was a couple of rubber bags —gas bags. The apparatus they had after that I don't distinctly remember. They put two or three in a line, attached them together with rubber tubes, made the gas in a gas retort, and forced it through the lamps.

514 x-Q. Where was this apparatus placed?

A. On Mr. Myers' bench in the shop.

515 x-Q. Did you see any mercury tube connected with it?

A. There was a glass tube with a bottle of mercury on the bottom of the tube. I don't remember seeing it attached to the lamps.

516 x-Q. Was there more than one mercury tube?

A. I don't remember whether there was one or two.

517 x-Q. Did you see any other chemical apparatus connected with that exhausting and filling apparatus?

A. I have seen them use melted sodium. I believe that there was bottles of chemicals that the gas run through besides the sodium.

518 x-Q. Was this exhaustive and filling apparatus mounted permanently in any place?

A. I can't remember for certain whether it was built permanently in Walker street or not. I know the retort used to be removed every time they got through with it.

519 x-Q. What retort?

A. The retort they made the gas in.

520 x-Q. When you say that the exhausting and filling apparatus was on Myers' bench, do you mean it was permanently fixed to Myers' bench?

A. I say I don't remember whether it was permanently fixed or not.

521 x-Q. How often was it used?

A. That I couldn't say; there was no regular time for using it.

522 x-Q. Was it put up every time it was used and then taken down?

A. I have stated that I don't know whether it was permanently or not. I don't remember what kind of an apparatus it was. It was something in form of a rack or shelf. That is all I can tell about it.

523 x-Q. Do you remember anything of a screen being used to show the form of a carbon in the lamp?

A. I think I remember seeing a screen one night when they had an exhibition in the office. They had some magnifying glasses. That is about all I remember of it.

524 x-Q. Was that the only time you ever saw the screen?

A. That is the only time.

525 x-Q. How often were you in the front office?

A. I don't know. I might perhaps be two or three times a day in it. The screen I saw was after the exhibition was over.

526 x-Q. Do you know about any person ever coming to see the lamps. I don't refer to exhibitions they made.

A. I have seen gentlemen around the place looking at them trying how far they could see to read from them.

527 x-Q. How often?

A. I don't remember whether I have seen it more than once or not.

528 x-Q. Do you wish to be understood as saying that Sawyer & Man never made but one arch-shaped carbon lamp?

A. I don't remember of any other.

529 x-Q. Are you willing to swear that they never made any other?

A. I don't remember of any other. I wouldn't swear to it.

530 x-Q. Are you willing to swear that they never used a paper carbon lamp?

A. I am willing to swear that I never saw or heard of such a thing till some time after I got through with Sawyer & Man work.

531 x-Q. Then you are not willing to swear that they never used a paper carbon lamp?

A. I never saw them use one.

532 x-Q. That don't answer the question. Please answer it?

A. Or heard of them using such a thing.

533 x-Q. That don't answer the question. Please answer it?

A. I am not willing to swear to something I don't know anything about.

534 x-Q. Were they in the habit of telling you all they were doing there?

A. They were not in the habit of telling me *all* that they were doing, but I think if there was anything like that I would be apt to know something about it.

535 x-Q. What do you mean by "like that"?

A. The like of paper carbon, or anything of that description.

536 x-Q. And yet you didn't know what they were doing in the crucibles you saw?

A. I don't remember—I don't know what they would be doing with the crucibles.

537 x-Q. Didn't you ask any questions about operations that were going on there?

A. I have asked lots of questions.

538 x-Q. Did Sawyer or Man, or old Mr. Sawyer, answer all your questions?

A. No, sir; I can't say they would answer all.

539 x-Q. Didn't they rather snub you?

A. No, sir; they did not.

540 x-Q. Don't you know that there was a number of things going on there that you knew nothing about?

A. There was things going on there, when it did not concern me, that was going on any way secretly—that I wouldn't ask questions.

541 x-Q. Wasn't your work principally brass-work?

A. Yes, sir; brass and copper. It was principally copper.

542 x-Q. Were all the carbons they used treated in oil, or hydro-carbon gas?

A. Hydro-carbon gas is something I don't know anything about. I don't know what it is, without it is explained to me. The carbons was all, I believe, treated in oils of some kind. I think I have seen it done in naphtha; I am not sure.

543 x-Q. After a carbon was treated, could you tell what the original carbon was?

A. I couldn't see that there was much difference after treating than they were before treating, except they might be a little thicker and a little brighter.

544 x-Q. Did you ever have treated carbons to put in lamps, the original carbons of which, before treatment, you never saw?

A. The placing of the carbons in the lamps was not a part of my business.

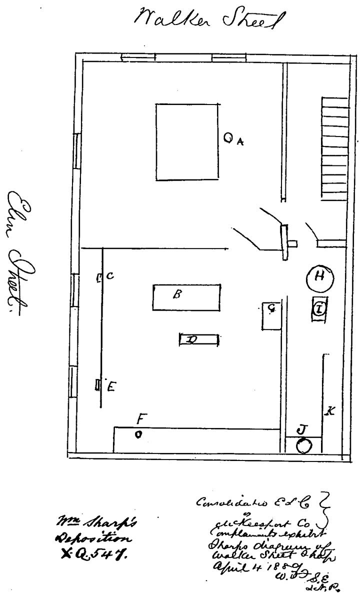
545 x-Q. Did you ever see treated carbons, the original carbons of which before treatment you did not see?

A. I couldn't say anything about that.

546 x-Q. Do you think it is an easy matter to tell what kind of carbon a treated carbon originally was?

A. I never took much notice of them.

547 x-Q. Please make a plan of the rooms at Walker and Elm streets, showing the position of your bench, Mr. Myers, the machinery, office, boiler, boiler room, water closet and the whole thing, and any other rooms



there were in connection with Sawyer & Man's business?

Adjourned for one hour.

Resumed after luncheon.

A. I have made and produce a sketch—A is Mr. Edward Sawyer's desk, B the lathe, C William Sawyer's vise, D first dynamo, E is my vise, F is Mr. Myers' bench, G second dynamo, H boiler, I the engine and J water closet.

548 x-Q. What is the place marked K?

A. The place marked K is an opening, I believe, between the first floor and the roof.

549 x-Q. What occupied that space, if anything?

A. On the second floor it was not occupied by anything, it was fenced round, if I can remember.

550 x-Q. Wasn't the water closet J between that space K and the engine?

A. I think not.

551 x-Q. Do you remember about a pump for exhausting the lamps?

A. I don't know of any particular pump with the exception of the glass tube and the bottle of mercury that I have mentioned before; I don't know of that being as a pump any further than Mr. Man spoke to me about it recently.

552 x-Q. How closely were you at your bench E?

A. I was working from the bench to the lathe B principally.

553 x-Q. At which were you the greater part of the time?

A. I think at the vise.

554 x-Q. When working there your back was to the balance of the room, was it not?

A. Back of the bench, this way, I faced the window.

555 x-Q. Is the room in which Mr. Sawyer's desk appears what you have referred to as the office?

A. Yes, sir.

556 x-Q. Did you know all that usually went on in the office?

A. No, sir.

557 x-Q. Do you know how much they burned the lamps in the office?

A. No, sir; I don't know how *much*.

558 x-Q. Do you know that Mr. William E. Sawyer was setting up lamps, putting in carbons, testing carbons and making measurements in the office?

A. No, sir; I don't know as I knew *that*. I know that there has been lamps put up, some on the wall and some on the chandelier. I have seen him filing carbons. I don't know about setting up and testing them. I may have seen him do such things, but I being working at my vice E, or at the lathe B, could not see much in the office.

559 x-Q. How many lamps were on the chandelier?

A. I couldn't say whether there was three or four.

560 x-Q. How many lamps were put up around the room, not on the chandelier?

A. I have no distinct recollection of that. I don't know of more than three or four. I know there was one on the office side of the partition, between the office and the workshop. I believe there was one on the front of the building between the windows. There was one I know; whether there was more than one, one or more, on the Elm street side. I don't remember seeing anything on the stairway partition.

561 x-Q. Do you remember anything about a hand-lamp on Sawyer's table?

A. I have no recollection of a hand-lamp on Sawyer's table, but I have seen a picture of it in the "Scientific American."

562 x-Q. About these chandelier lamps; did they stand upright or were they pointed downward, pendent?

A. To the best of my knowledge they were always standing.

563 x-Q. Do you remember any other tables or desks in the office room?

A. No, sir; I don't know that I do.

564 x-Q. Did you ever see any testing instruments in the office?

A. I don't know hardly how to answer that question. I believe there has been such a thing in there, or some mention of getting one.

565 x-Q. Were there any cupboards in the workshop?

A. No, sir; I believe not. I believe there was something—something with a piece of black cloth around Mr. Myer's bench for a time. I know the cloth took fire and burned up. I believe it was a small closet with some kind of chemicals in.

566 x-Q. Were there any galvanic batteries in the office room?

A. I never saw any batteries further than the two dynamos.

568 x-Q. But they weren't in the front room, were they?

A. No, sir.

569 x-Q. Please tell me what money, if any, you have received from Mr. Russell or from anybody in any way connected with the Edison Electric Light Company in connection with the matter of the testimony you have supplied or promised to supply them in reference to Sawyer & Man?

A. I received ten dollars last Friday; I was out of pocket money; I asked Mr. Griffin if he could let me have a little change, as I was getting short, and he gave me the ten dollars. I have made no agreement whatever. Mr. Russell gave me ten dollars to come down to New York from Ansonia. I made no arrangements for what testimony I should give. I didn't know when I came down really what I was coming for. I made no arrangements for my testimony or money.

570 x-Q. How much did you receive when you came to New York the first time?

A. When I got through with the testimony Mr. Tomlinson gave me sixty-five dollars.

571 x-Q. What wages were you receiving at Ansonia?

A. Three dollars a day.

572 x-Q. Did Mr. Russell tell you that it would be

made all right with you if you came to New York and made your statement or anything to that effect?

A. I don't remember that he did.

573 x-Q. Did you have any such expectation when you came?

A. I had no such expectations as that. I expected to be paid pretty liberally for my loss of time and trouble.

574 x-Q. Had you known Mr. Russell before that time?

A. I don't know that I ever saw him before.

575 x-Q. Do you mean that you came to New York at the request of an entire stranger, risking your time and trouble?

A. I mean to say that there was about a half a dozen men came chasing me around at Ansonia, wanting to find out something, I don't know what. Mr. Russell spoke pretty frank to me. He gave me some idea what was wanted. I came down and thought I would give my evidence, as I did not suppose it would amount to anything, and as that might put an end to people running after me.

576 x-Q. Am I to understand, then, that you came to New York with Mr. Russell, an utter stranger, without any understanding with him?

A. I didn't come down with Mr. Russell, and there was no understanding as to money.

577 x-Q. Money is not the only valuable consideration. Was there any understanding as to anything else in the shape of a consideration?

A. No, sir; there was not. My understanding as to coming down with an utter stranger was that I was coming to my old home and to see my own people. If it had been in any other place I wouldn't have come.

578 x-Q. After you had made your statement did you have any understanding in regard to being called as a witness?

A. No, sir; the only understanding I had, as I told Mr. Tomlinson, was, as I was going out of the office, that I hoped—I can't give it in just the same words—that he would not bother me any more. He told me that he would if it was needed.

579 x-Q. After that when did you next see Mr. Russell?

A. I believe it was last Tuesday morning.

580 x-Q. What did he say to you?

A. I can't just remember what he said to me then. He spoke to me and asked me if I didn't know him. I told him "Yes." He told me that these people wanted to see me again, that they had made a change and that Mr. Tomlinson was out of Mr. Edison's employ, and that there was a man by the name of Dyer in his place. That is about all I remember. He told me that Mr. Dyer wanted to see me.

581 x-Q. Did he say to you that it would be all right if you came over?

A. I don't know that he did.

582 x-Q. You don't know that he didn't, though?

A. I don't know really particularly what he did say. Of course I expect to have my time and expenses paid.

583 x-Q. What else do you expect?

A. I have got no expectation.

584 x-Q. You have bought a house lately, haven't you?

A. I have, sir.

585 x-Q. Now, referring to the time you were at the Walker and Elm street shop, what other work, if any, was done besides making lamps there?

A. I saw Mr. Sawyer tinkering with a meter or trying to get up a meter to measure an electric current, and there was something done concerning some switch. I believe I made some patterns and they got castings. That is about as much as I remember of them. I done some work at it, but I don't remember what; I don't remember finishing them.

RE-DIRECT BY MR. GRIFFIN:

586 Re-d. Q. Did you ever see Mr. Broadnax before you met him at this examination?

A. I did, sir.

587 Re-d. Q. How did you come to see him ?

A. The first I remember of seeing Mr. Broadnax, he was one of the men, as near as I can judge, that came to see me in Ansonia.

588 Re-d. Q. About what did he talk to you ?

A. I can't remember just exactly just what it was he said. He spoke about Sawyer-Man, the Sawyer-Man lamp. I can't remember what it was he asked me. I suspected there was some trouble about it, and I didn't want to have anything to say about it.

589 Re-d. Q. Did he come to see you again ?

A. No, sir.

590 Re-d. Q. Did you see him again ?

A. Mr. Man took me over to his office, spoke a few words concerning what I knew about the lamps, then. I believe it was last Tuesday night—Monday, I guess it was—I am not sure whether it was last week or not—I think it must be the week before last—I know it was before Mr. Russell came to see me—I think it must have been Tuesday night of week before last, I had a note given to me to go and see Mr. Broadnax.

591 Re-d. Q. Did you go ?

A. Yes, sir.

592 Re-d. Q. What did he talk to you about ?

A. He wanted to know what I had done on lamps and different things when I worked for Messrs. Sawyer & Man.

593 Re-d. Q. Did he ask you about paper carbons ?

A. Yes, sir; wanted to know if I hadn't seen them. I told him that I hadn't seen any or heard of any, only what I had seen and heard of in Ansonia.

594 Re-d. Q. You say Mr. Man took you once to Mr. Broadnax; how did Mr. Man come to see you?

A. Mr. Man was settling the business for the house I have been lately buying, and from there he took me over to New York, here somewhere. He took me to his office; from there I went with Mr. Man to Mr. Broadnax's office.

595 Re-d. Q. From the time you first saw Mr. Russell in Ansonia until he called on you here in New York to ask you to come to see Mr. Dyer, did anybody

whom you know or believe as in any way connected with the Edison Company, or Mr. Russell, or Mr. Tomlinson, Mr. Dyer or myself come after you in any way?

A. No, sir.

596 Re-d. Q. Besides Mr. Broadnax and Mr. Russell, do you know any of the others who came to you at Ansonia.

Objected to as incompetent, the witness not having identified Mr. Broadnax sufficiently as a man who came to see him at Ansonia.

A. No, sir; I do not.

597 Re-d. Q. Was the Mr. Broadnax, who was examining you Saturday, the Mr. Broadnax you referred to in re-direct answer 587?

A. Yes, sir.

598 Re-d. Q. Do you remember Mr. Broadnax coming to see you at Ansonia, or not?

A. I remember a man who looks very much like him. When I got in conversation with him here in New York I asked him if he hadn't been to Ansonia to see me, and he said he had.

Adjourned till Tuesday, March 5th, at 11 o'clock.

Defendant's counsel here stated of record that the reason of his adjourning at 10 minutes to 4 is because he has a compulsory reference in the N. Y. Supreme Court in which an adjournment has been refused.

Adjourned till Tuesday, the 5th inst., at 11 A. M.

Tuesday, March 5th, 1889.

Met pursuant to adjournment.

Present—Mr. Griffin, for defendant; Mr. Kerr, for complainant, and Mr. Albon Man; and the examination of Mr. Sharp continued as follows;

599 Re-d. Q. You were asked in cross question 584 whether you had bought a house lately, and you answered that you had. Did you ever nention this purchase to me or any of the Edison people?

A. No, sir.

600 Re-d. Q. Has the matter anything to do with your testimony in this suit?

A. It does not.

601 Re-d. Q. Going back to your work for Mr. Man in Brooklyn, did you do any work for him there except as you have already testified?

A. I got a recess from the shop; I don't remember how it was; and the switches we were talking about yesterday—the castings—I remember that I formed some slides of sheet-brass. That is about as much as I remember on that arrangement. I know that Mr. Man paid me for them when I brought them into the shop.

602 Re-d. Q. Were you ever at Sawyer's shop, 41 or 43 Centre street?

A. No, sir, I was not.

603 Re-d. Q. At your home or shop in Brooklyn did you ever bore several dozen glass base plates for Mr. Man or Mr. Sawyer?

A. I have a slight recollection of drilling one or two holes, but no such quantity as one or two dozen.

604 Re-d. Q. Where do you remember drilling these holes, in Brooklyn or at Sawyer & Man's?

A. I think I did the first ones at my own home, if any, and I think likely that I done some in Walker street.

605 Re-d. Q. You have testified as to a lamp with a circular carbon. Did you ever see or hear of as many

as fifty of those lamps being used at Sawyer & Man's?

A. No, sir.

606 Re-d. Q. How many did you see or hear of?

A. I don't remember of more than one, and that is only by making the clamps for holding the carbon.

607 Re-d. Q. Did you ever see as many as two hundred lamps of any kind at Sawyer & Man's?

A. I have not.

608 Re-d. Q. What is your best recollection of the entire number of lamps from the beginning to the end of the time you were at Sawyer & Man's, at Howard and at Walker street?

A. I don't remember distinctly of seeing more than one.

609 Re-d. Q. I am not referring to lamps with circular carbons, but lamps of every kind? (The Master rereads the Re-d. Q. 608.)

A. I have no recollection of seeing more than one.

610 Re-d. Q. How many lamps, to your best recollection, were made at Sawyer & Man's all the time you were there; I mean of all kinds.

A. At that one particular place?

611 Re-d. Q. I mean the lump total of lamps at all the places of Sawyer & Man where you worked?

A. I don't believe I have seen more than fifty.

612 Re-d. Q. What is the greatest number they had at any one time?

A. I don't know that I have ever seen more than a dozen at one time.

613 Re-d. Q. Were these fifty lamps new lamps, or were some made up of the parts of the preceding lamps?

A. Well, the lamps was mostly all changed one way or other.

614 Re-d. Q. What would they do to the lamps in changing them?

A. Make some difference in the conductors or new works, new holders, or something of that kind. I can't think of all the changes that was made in them.

615 Re-d. Q. Does your total of fifty lamps cover all these changed lamps as well as the original lamps?

A. Yes, sir.

616 Re-d. Q. How often were these lamps changed?

A. That is something I can't answer direct. There was no stated time for changing them. I suppose, when the lamps didn't work, they would make some different change in them. I can't tell how often they were changed. That is as near as I can give it.

617 Re-d. Q. You spoke, on cross-examination, of putting Canada balsam on the glass globe or base of the lamps. Did you put it on hot glass or cold?

A. The glass was, towards the last, all made hot to expel all the air.

618 Re-d. Q. What do you mean by "towards the last"?

A. Towards the last of my working in Walker street.

619 Re-d. Q. When you took the lamps apart, did you have to warm the glass?

A. Sometimes I had to.

620 Re-d. Q. Generally, did you have to?

A. No, sir; once in a while they would stick a little tighter than others.

621 Re-d. Q. You talked about cleaning the works of the lamp and taking them apart; what do you mean by that?

A. In taking an old lamp apart it would get kind of smoky, or they would be smoking, and I would have to clean that all off—get everything perfectly clean before putting them together again.

622 Re-d. Q. What parts would you clean?

A. All the parts in the lamp—the metal parts and the carbons and the carbon holders.

623 Re-d. Q. How did the lamps become smoky?

Objected to as incompetent.

A. By the carbons or pencils burning out.

624 Re-d. Q. If a lamp was brought to you with a burnt-out carbon, how long did it take you to take the lamp apart, clean it, and do such things as were ordinarily necessary, and put the lamp together again?

A. As near as I can think of it, it would take about two hours on an average.

625 Re-d. Would this two hours include the time taken up in charging the lamp with gas?

A. No, sir.

626 Re-d. Q. After the lamp was charged with gas, what had to be done to it, if anything?

A. They used to be sealed with sealing wax.

627 Re-d. Q. Who, besides yourself, did you ever see cleaning the inside works of the lamps?

A. William Sawyer—the old gentleman.

628 Re-d. Q. Any one else?

A. I don't know whether Mr. Myers would take a hand in it once in a while to help out; I can't remember.

629 Re-d. Q. Besides the one lamp you mentioned with a circular carbon, did you see any other lamps with metal clamps for the carbon?

A. They all had a kind of metal socket, with a carbon or pencil holder, with the carbon holders pressed into them.

630 Re-d. Q. I refer only to the carbon which was made incandescent and not to the carbon holders. Besides the one lamp with the circular carbon, did you see any other lamps in which the carbon pencil itself was held by metal clamps?

A. I never saw a lamp held by metal clamps.

631 Re-d. Q. In the lamp figure 52, page 87 of the Sawyer book, as to which you testified, how was the circular carbon clamped or held (witness shown the book)?

A. It was held by two flat carbons—held in a socket as I have mentioned, and two other flat pieces held together by platinum screws and nuts.

632 Re-d. Q. I understood from you yesterday that you wished to correct part of your statement about seeing Mr. Wallace fire out the Sawyer feeder lamps at Ansonia. What correction do you wish to make?

A. I don't know whether I said that I saw or heard of it. When I come to think of it I remember that I was told of it. I was in the same building, but did not see anything of it personally—did not see it personally.

633 Re-d. Q. Did you personally see the parts of the feeder lamps lying around as you testified?

A. Lying around in the yard?

634 Re-d. Q. Either the yard or the rooms at Ansonia?

A. I have seen them laying around the rooms a long time before they was thrown out.

Re-cross-examination by Mr. Kerr:

635 Re-x-Q. When did Mr. Broadnax tell you he had been to Ansonia to see you?

A. He did not tell me when he had been there to see me. I asked him if he wasn't one of the gentlemen that came to see me and he said he was.

636 Re-x-Q. When?

A. I believe it was when I went with Mr. Man to his office. Some time recently here in New York City.

637 Re-x-Q. Was Mr. Man present at the time you allege you had such conversations?

A. I believe he was in the room with me.

638 Re-x-Q. How long were you there?

A. Wasn't there more than two or three minutes.

639 Re-x-Q. Didn't Mr. Broadnax deny seeing you at Ansonia?

A. I don't know that he did.

640 Re-x-Q. Well, then, you don't know that he said he did see you?

A. I know that he said he did or I very strongly thought he did. I don't like to say right out that he didn't or that he did.

641 Re-x-Q. Are you prepared to say that Mr. Broadnax ever talked to you on this subject until you met him at his house in Brooklyn recently—I mean as to the lamps made by Sawyer & Man in 1878 and 1879; please answer this question, yes or no?

A. There was a few words said about the lamps. Mr. Broadnax hadn't time to speak about it. This was at Mr. Broadnax's office, or in the room next to his office, when I went there with Mr. Man.

642 Re-x-Q. Are you prepared to say that Mr. Broadnax ever, before that time, spoke to you on the subject of Sawyer & Man lamps; please answer, yes or no?

A. Yes.

643 Re-x-Q. That you swear was at Ansonia?

A. Well, I can't swear that that was really the man or not, only as I remember him by sight.

644 Re-x-Q. After the year 1879, when did you next see Mr. Man?

A. I don't remember seeing Mr. Man from 1879 until the time that Mr. Man settled my house business; as near as I can think it was about two months ago.

645 Re-x-Q. Did you ever use anything to pack the flanges at the base of the lamps?

A. Yes, we used to put paper between the metal and the glass.

646 Re-x-Q. What was the shape of that paper?

A. Shape of that paper was in rings to fit over the glass globe, and one on the bottom had a hole large enough to allow the bottom piece to come through—the cocks or caps—pieces that came through from the lamp.

647 Re-x-Q. How did you get the paper washers?

A. I used to make them.

648 Re-x-Q. How did you make them?

A. As near as I can recollect, we used to cut them out with a knife and a pair of scissors.

649 Rex-Q. Did you ever have any special tools to cut them out?

A. I don't remember ever seeing any.

650 Re-x-Q. Were these paper washers all the same size?

A. They wasn't exactly the same size. I don't believe you could cut two exactly alike. We made a small washer for clamping the works of the bottom glass. That, I think, we had a little brass punch for; I won't be sure, though.

651 Re-x-Q. Were the lamps all the same diameter?

A. So far as I can remember, they was towards the last. No, I don't think they were all the same size; not exactly. There might be a quarter or a half an inch difference.

652 Re-x-Q. What wages do you make now?

A. I don't understand that question.

653 Re-x-Q. What are you paid for a day's work at the present time?

A. I am paid three dollars a day. My wages for Sawyer & Man I don't think was ever more than two dollars and a half.

QUESTION BY DEFENDANT'S COUNSEL:

654 Q. Have you any correction to make as to your wages at Ansonia at the time you came to see Mr. Tomlinson in your answer to cross-question 571?

Said question read to witness.

A. I suppose about that time I was only getting two dollars and a half, but after the election of Cleveland my wages was reduced half a dollar a day.

WILLIAM SHARP.

Sworn to before me,

WILLIAM T. FARNHAM,

[L. S.] Notary Public and Special Examiner.

End of Sharp's McKeesport Deposition.

Complainant's counsel requests the defendant to put the sworn statement of William Sharp made by him in June, 1886, in evidence or a copy of the same made by the Examiner and so certified.

Sharp's Statement.

IN THE MATTER

OF

The litigation now pending between SAWYER & MAN and THE EDISON ELECTRIC LIGHT COMPANY.

WILLIAM SHARP, being duly sworn, testified as follows:

BY MR. TOMLINSON: Q. Please state when you first met Mr. Albon Man, or Mr. Wm. E. Sawyer?

A. I knew Mr. Man for some time prior to the experiments of Sawyer & Man on electric lighting; Mr. Sawyer I met for the first time at the shop of Arnoux & Hockhausen, No. 2 Howard street.

Q. Please state in detail what was the first work done by you for either Mr. Sawyer or Mr. Man relating in any way to electric lighting?

A. I was living in Brooklyn and had a lathe and some tools at my house and did work there. The first work that I did for either Sawyer or Man was done at my house in Brooklyn. Mr. Man brought me some glass globes and some blocks of gas retort carbon, and stated to me that he desired the carbon filed down and a lamp made. I don't now remember in detail just the character of the lamp. I think I made two lamps, but not more than two. I got pieces of metal and made them in the proper size and shape; as nearly as I can now recollect, the lamp contained a globe of glass about six inches long, and about three or four inches in diameter. I made the supports for the carbon of the lamp and they were inserted through the neck of the lamp globe into the lamp and fastened there by nuts and paper washers. I worked the blocks of carbon down until I got two pieces of carbon, one of about the size and shape shown in No. 1 of the drawing marked "A," the other a strip of carbon of about the size and shape shown in No. 2 of the drawing, marked "A." The circular carbon was, I think, an experiment, and I don't think it was ever put in a lamp. The carbon worked down to the shape shown in No. 2, was the size and general shape of the carbon I put in the lamp. These lamps were so made that the carbon could be replaced. I gave the lamps to Mr. Man. Mr. Man, while I was working on these two lamps, at my house, came at least a half a dozen times to my house to instruct me in the work, and occasionally helped me do the work. I should think I was working on these lamps about a month. I have no knowledge whether while I was making these lamps at my house, anybody else was making lamps for them. I did not know that it was a lamp that I was working on until I went to Mr. Man's office to get my money for it, when he asked me if I knew what I had been making and I told him no; he then told me that it was an electric lamp. I am quite confident that I made but two lamps and two pieces of carbon. The carbon was gas retort carbon which I worked on as I have said. About a month after I had delivered this lamp, I saw it for the first time in Sawyer's place, at No. 2 Howard street; I saw it lit at intervals, during a month or two, and I understood that occasionally they would light it and show it. I did not understand that they burned it steadily. They would merely run it to incandescence for a few minutes at a time, and it was their custom to replace the carbon.

Q. When next did you work for Sawyer & Man?

A. I entered their employ while they were at No. 2 Howard street, and remained with them after they were at Elm and Walker streets, leaving them, as nearly as I can now recollect, about May, 1879.

Q. During this time were you at their laboratories or shops during the working hours of each day?

A. Yes, sir.

Q. During this period were you familiar with the work that was done at these laboratories?

A. Yes, sir.

Q. And with the various experiments that were conducted?

A. Yes, sir.

Q. Was any attempt made to conceal from you what was being done, or did you have free access through the laboratory, and were you generally familiar with all that was done while you were in their employ?

A. I had the privilege of seeing anything that was going on and am generally familiar with what was done. I am not an electrician but am an expert mechanic and was largely employed on mechanical work.

Q. What was the general nature of the work in which you were engaged?

A. Chiefly on the mechanical parts of the lamps that were made; I also worked in forming the carbons to the desired sized.

Q. During the time that you were employed by them what was the general type of lamp on which they were experimenting, or making, as nearly as you now remember?

A. The lamp contained a glass globe about eight inches long by about two inches in diameter. The base of the globe, by nuts and washers, was fastened to glass plates; the glass plate and the globe were clamped together by metal rings. The interior part of the lamp was fastened mechanically to the base of the lamp in different ways. The base of the lamp was then surrounded with melted sealing-wax; after this was done the base was placed in a metallic shell and filled with bees-wax. The interior of the lamp contained a short pencil of carbon; a disk of soapstone or metal separated the illuminating part of the interior from radiators such as are shown in figure 1 of Letters Patent 205,144. The shape and character of these raidiators, however, differed; some being serpentine and some of other shapes.

Q. From the time that you first were regularly employed by them until the time you left them, which, as nearly as you can recollect, as I understand you, was from September, 1878, to May, 1879, how many completed lamps in all were made by them?

A. I should say a couple of dozen; I am sure that not more than fifty were made.

Q. What was the character of carbon usually employed in these lamps as the incandescent conductor?

A. Usually pencils made from gas retort carbon.

Q. What was the shape and dimensions of these pencils?

A. Straight pencils about half an inch in length, varying in diameter from three sixty-fourths to one sixteenth of an inch.

Q. Were these lamps so constructed that they could be taken apart and new pencils of carbon inserted?

A. They were.

Q. Do you know, and if so, state whether it was their habit to take their lamps apart and replace the pencils which were consumed, by new pencils of carbon?

A. I do know that it was their habit to do so.

Q. What is the longest period during which you have known one of their lamps to remain at continual incandescence?

A. Not over an hour; certainly not over two.

Q. Do you ever remember to have been told of a lamp remaining incandescent for over that time?

A. No; I do not remember.

Q. If any lamp had remained incandescent for two or three days at a time, or for a week or two, do you not think you would have been likely to have known of it, or have heard of it?

A. I do.

Q. Did you ever know or hear of a lamp remaining at continual incandescence for as long as a day?

A. I never did.

Q. If one had burned as long as that, would you not have been apt to have known or heard of it?

A. I think I should.

Q. During the entire time that you were there, did they make any lamp which you would consider a practical lamp? I mean by that, one that could be made and sold commercially, and actually used for purposes of illumination?

A. No, sir; I think their lamps were merely experiments.

Q. Did you ever know of their making any test of the life of their lamps, or keeping any records as to how long the lamps would burn?

A. No; I don't know anything about that.

Q. Did you ever know of their doing any carbonization while they were at Howard, or at Elm and Walker streets? By carbonization I mean taking some material such as wood or paper in its natural state, and making it into carbon by the heat of the furnace?

A. No.

Q. If this had been done to any extent, or if carbons thus made had been used to any extent, would you not have been apt to have known of it?

A. I would.

Q. Then, as I understand you, the carbons which were used, so far as your knowledge goes, were carbons purchased by them and reduced mechanically to the desired size?

A. Yes.

Q. Did you ever know or hear of their carbonizing paper, wood, or other substances?

A. I never did.

Q. Did you ever know or hear of their using or trying in their lamps carbons made from paper?

A. No, sir.

Q. If this had been done would you have been apt to have known of it?

A. I would, probably.

Q. Did you ever know or hear of their carbonizing any fibrous or textile material?

A. I never did.

Q. If they had done so, would you have been apt to have known of it?

A. I think I would.

Q. Do you know of their using or trying any carbons other than gas retort carbon, and, if so, please state the fact as you understand it?

A. I remember their getting what were called willow charcoal; these were what is generally known as artists' crayons. They were filed down to the desired size. These crayons were always treated by putting a shell of carbon on the outside. The willow crayons are the only kind of carbon, other than gas retort carbon, which I ever knew them to try or use. I remember some carbons called French carbons, such as are used in arc lights, but these I understand to be gas retort carbons.

Q. In their laboratories did they have extensive apparatus for the conduct of experiments?

A. They had pretty fair tools, but very little chemical apparatus, as I understand it. The shop more resembled a mechanic's workshop.

Q. Do you know whether they had an air pump of any kind?

A. I never saw one; and I don't think they had one. I think that for a short time they had some sort of apparatus for taking the air out of the globes with water; but they used to send their lamps out. Towards the last they had Mr. Stillman came up to the shop; they then had some apparatus to charge the globes with gas.

Q. Did you ever know of their using in any of their lamps an incandescent conductor as long as two or three inches and as fine as a horsehair?

A. No, sir.

Q. If they had ever used such a conductor while you were with them, would you have known of it?

A. I certainly would.

Q. Did you ever know, or hear, of their experimenting in any way with such a conductor?

A. No, sir; I never did.

Q. Had they ever done so, would you have been apt to have known or seen or heard of it?

A. I certainly would.

Q. If they had had any apparatus for the obtaining of a high vacuum, would you have been apt to have known of it?

A. I think I would.

Q. Did you ever know of their having such an apparatus?

A. I never did.

Q. Who, besides yourself, worked at the shops of Sawyer & Man?

A. Principally Mr. Myers, young George Sawyer, William E. Sawyer and William Sawyer, Sr.

Q. Did you ever hear of a Mr. Keating?

A. I believe Keating did some work for them before I went with them. I have heard of him and seen him.

Q. Did you ever know of the interior of their lamp being enclosed in a globe entirely of glass?

A. I never did.

Q. Afterwards did you work with Mr. William E. Sawyer when he was in Ansonia?

A. I did.

Q. Did you assist him in his experiments there?

A. Yes, sir.

Q. Do you know of any lamps being made with a circular carbon, such as shown in the drawing of Patent 317,676, while you were in New York?

A. Yes, I did work myself on a lamp containing such a carbon; I don't think over two such lamps were made. I think the round carbon was too bothersome. They made many more of the other kind of lamp.

Q. You say you worked with Mr. Sawyer after his separation from Man at Ansonia?

A. I did.

Q. What kind of lamp was he then at work upon?

A. The feeder lamp.

Q. Do you know whether he considered that type of lamp better than the lamps he had made in New York?

A. I believe he did. I think he considered it a better style of lamp.

Q. Did you ever know of his making a lamp at Ansonia that could be considered practical?

A. I never did.

Q. In the lamps made in New York, were they troubled with blackening of the globe of the lamp?

A. They were; they globe would always blacken if they burned them long enough.

Q. When the globe would blacken, was it their habit to take the lamp apart, clean the globe and put in a new carbon?

A. It was.

Q. When was the first you ever heard of paper carbon being tried by Sawyer, or anybody with whom you were connected?

A. Some time after Sawyer had left Ansonia I knew of Mr. William Wallace, Sr., trying to carbonize a piece of paper, but I don't think it was ever put in a lamp, as far as I know. He tried to carbonize it, I think, between two pieces of iron. I believe he was led to this by the publication of Edison's experiments.

William Sharp.

Subscribed and sworn to before me this 17th day of June, 1886.

John C. Tomlinson,
Notary Public,
N. Y. Co.

The above statement was made by Mr. Sharp in the presence of Mr. James A. Russell and Martin R. Winchell and Mr. J. C. Tomlinson, the witness being interrogated by Mr. Tomlinson, and questions and answers being taken by Mr. Winchell in short hand.

Griffin's McKeesport Deposition.

Tuesday, March 5th, 1889.

Walter K. Griffin, being duly sworn on behalf of defendants, says:

I am one of the counsel for defendant. I first saw the witness William Sharp the morning before his examination was begun. I met him at the office of Mr. Dyer, 40 Wall street, New York City, and as the examination of the witness Hochhausen was about to proceed, I requested Mr. Sharp to come with me to my office, 11 Pine street. Mr. Russell accompanied us. On arriving at my office I failed to find a statement of Mr. Sharp, which had been given me some time ago, among my papers, and I proceeded to ask Mr. Sharp such questions, as in my opinion, were necessary to prepare myself to examine him in this case. I did not find the statement until the next day, and to the best of my recollection I never referred to the statement in any way to Mr. Sharp. On Friday, I think it was, Mr. Sharp, at the close of the examination for the day, said that as he had not been to the shop his pocket money had about run out, or something to that effect. I had no change less than ten dollars and handed him that. He objected to taking it, saying he only needed some small change, but I told him he had better keep it.

Walter K. Griffin.

Sworn to before me,
William T. Farnham,
[L. S.] Special Examiner and Notary Public.

END OF THE MATTER TAKEN FROM THE McKEESPORT CASE.

Defendant's counsel reserves the right to interpose objections hereafter to the foregoing described depositions.

Further hearing adjourned subject to notice or agreement.

New York, April 18, 1890.

Defendant's counsel appear and pursuant to the reservation made and noted upon the record at the hearing on April 7th, 1890, offer the following objection.

Counsel for defendant objects to the introduction of the depositions of Thomas A. Edison, Charles Batchelor and Francis R. Upton, above referred to as not admissible under the stipulation of January 28, 1890.

Counsel for defendant also gives notice that if the depositions of Thomas A. Edison, Charles Batchelor and Francis R. Upton, taken and used in the McKeesport suit are to be used in the present suit they desire the said witnesses to be produced for cross-examination and that unless the said witnesses are so produced they will, on that ground, object to the introduction of the said depositions.

U. S. CIRCUIT COURT,

Southern District of New York.

The Edison Electric Light Company, Complainant, vs. The United States Electric Lighting Company, Defendant.	In Equity. No. 3445.

New York July 1, 1890.

Met pursuant to notice.

Present—R. N. Dyer, for complainant; S. A. Duncan, for defendant.

George F. Barker, a witness produced on behalf of complainant, being duly affirmed, deposes and says in answer to questions by complainant's counsel as follows:

1 Q. Did you testify for the complainant in its *prima facie* case?

A. I did.

2 Q. I call your attention to the comparison made by Dr. Morton between the specific resistance of arc light carbons and of the carbon filaments of the defendant's lamps, contained in answer 50 of his deposition. In view of the data given by Dr. Morton, do you still adhere to the position taken by you in your *prima facie* deposition in this case that the high specific resistance called for by the first claim of the patent in suit is a specific resistance higher than that of some of the carbons used for electric lighting before the date of the patent in suit, and that the defendant's lamps have this high specific resistance?

A. I have read the testimony of Dr. Morton referred to, and I see no reason in view of it to modify the opinions expressed in my *prima facie* deposition upon either of the points in question. The position taken by me and referred to in the question suggested a comparison which was intended to be made with those arc light carbons which had the lowest specific resistance, and which therefore were best adapted for the purposes of arc lighting. It did not intend, on the one hand, to include those arc light carbons which, by reason of imperfect manufacture or of highly porous material, departed widely from the most desirable conditions for such carbons; or, on the other hand, to include those carbons which were made with the intention of subsequently increasing their conductivity by plating with copper or other material. To illustrate what I mean I may refer to the fact that the specific resistance of carbons used before the date of the patent in suit in electric lighting appears to have been as low as 600 microhms; while the specific resistance of the carbon filaments of defendant's lamps varies from 3800 to over 6300 microhms, thus showing that the specific resistance of these filaments is at least from 6 to 10 times greater than the specific resistance possessed by carbons which were actually employed for electric lighting before the date of the patent in suit.

With reference to the question of the specific resistance of carbon, I find that Wilde, in 1874, in speaking of the resistance of the gas carbon which was used in the electric lamp of Lodyguine, states that the resistance of this carbon as a conductor of electricity is about 250 times that of platinum. So that if we call the specific resistance of platinum 9 microhms, the specific resistance of this particular gas carbon, according to Wilde, will be about 2250 microhms (Les Mondes, xxxvi., 183, 1875).

I find also that Farmer, in 1879, in speaking of the resistance of arc light carbons, says: "The resistance of some specimens which I have tested is about 1500 or 1600 times that of pure copper at 32 degrees." Taking the specific resistance of pure copper at 1.6

microhms, the specific resistance of the carbon measured by Farmer would be from 2400 to 2560 microhms (Prescott, Electric Lighting, 518, 1879).

Farmer also specifically states in the same article, in speaking of electric light carbon, that a carbon rod $\frac{3}{4}$ of an inch long and $\frac{1}{30}$ of an inch in diameter, has a resistance not far from half an ohm. This gives the absolute specific resistance of the electric light carbons referred to by him as 2956 microhms.

I find further that Fontaine in 1877 gives the mean linear resistance of a gas retort carbon of square section two millimeters on a side, which he used in the Konn lamp as 172 times that of a telegraph wire of the same length and of four millimeters diameter; the standard of resistance then in use in France. This would make the absolute specific resistance of the gas retort carbons measured by Fontaine about 630 microhms. If we calculate the relative specific resistance of this gas retort carbon from a table given by Fontaine in this connection, the value obtained would be 156 times that of a telegraph wire of the same length and four millimeters in diameter, which would give an absolute specific resistance for that specimen of gas carbon of 572 microhms (Fontaine Éclairage à l'Électricité, 218, 1877; or Electric Lighting, Higg's Translation, p. 178, 1878).

Moreover, I have myself measured carbons which were prepared by William E. Sawyer, as I believe, for use in the incandescent electric lamp proposed by him. These carbons were received by me from Mr. William Wallace, in Ansonia, Connecticut, who stated to me that they were so made by Mr. Sawyer at the time he was operating there in the spring of 1879, and by the process substantially which is described in the said Sawyer's Patent No. 211,262. These carbons were found to consist of a central core upon which had been deposited a layer of condensed carbon forming an outer shell. The central core, understood to be of Carré carbon, was found to have a specific resistance of 3,700 microhms. The absolute specific resistance of the entire Sawyer carbon was found to be in five specimens as follows: No. 1, 1,310 microhms; No. 2, 1,050 microhms; No. 3, 1,360 microhms; No. 4, 1,060 microhms; and No. 5, 1,100 microhms. Evidently, therefore, the deposited carbon has a very much lower specific resistance than that of the entire rod. And calculation gives the absolute specific resistance of this layer of condensed carbon deposited by the Sawyer process as 826 microhms.

It should further be observed, I think, that of the forty-one electric light carbons measured by Dr. Morton, eleven have a specific resistance varying from 3,252 microhms to 3,694 microhms; these carbons having, therefore, a lower specific resistance than that given by him as the specific resistance of the lowest of the filaments of the defendant's lamps, and only a little more than one-half that of the highest.

From the patent of Sawyer, above referred to, it would appear that the direction of progress aimed at by inventors of incandescent lamps before the date of the patent in suit was that of using dense carbon of low specific resistance. For example, the patent in question speaking of the carbon produced in gas retorts as well as of the molded carbon, says: "Neither the one nor the other quality of carbon is suitable for electric lighting by incandescence. In both there is a lack of homogeneity. The pencil is not sufficiently hard and dense * * * ." Then follows a description of Sawyer's process by which the solid deposit of carbon by electric action is made use of to obtain a more homogeneous and compact material.

3 Q. Please state how the unit of measurement of specific resistance employed by you differs from that used by Dr. Morton in his data ?

A. In my *prima facie* deposition I define the absolute specific resistance of a substance as "the resistance of a cubic centimeter of that substance expressed in ohms." Since the specific resistance expressed in ohms is a small fraction, it is the best practice now, I believe, to express it in microhms, or millionths of an ohm. Thus, for example, the absolute specific resistance of silver is 1.5 millionths of an ohm, or 1.5 microhms.

The following table gives the absolute specific resistances, at 0° C, of a few of the more common metals expressed in this way:

Silver	1.5	microhms.
Copper	1.6	"
Zinc	5.6	"
Platinum	9.0	"
Iron	9.8	"
Mercury	96.0	"

Dr. Morton's specific resistances are expressed relatively in terms of mercury taken as a standard. Inasmuch as the specific resistance of mercury given in the above table is 96.0 microhms, it is evident that the values given by Dr. Morton will be converted into microhms or units of absolute specific resistance, within four per cent. of their true value, by multiplying 100—*i. e.*, by simply removing the decimal point in cases where the value is expressed to two decimal places. Conversely, by dividing by 100, the values expressed in microhms may be converted into those expressed in mercury units within the same limit of errors; so that, for example, the 572 microhms mentioned in the last answer becomes 5.72 mercury units, and the 3,800 and 6,300 microhms become respectively 38.00 and 63.00 mercury units.

4 Q. Do you consider the comparison made by Dr. Morton in his 50th answer as a proper and satisfactory one, and as warranting the conclusion stated by the 52d question of his deposition, that the carbons in the defendant's lamps have a relatively low specific resistance ?

A. It does not seem to me that the comparison made by Dr. Morton in the answer referred to can be considered a proper and satisfactory one, or that the conclusion drawn from it in the 52d question of his deposition is a legitimate one; and this for the following reasons:

First, because he compares the specific resistance of arc light carbons, which are intended to be plated, with that of incandescent carbons.

It is a well-known fact that practically all of the electric arc light carbons at present in commercial use are electro-plated with copper; this practice having existed, as I understand, since as early as August, 1879. Judging, therefore, from the practice of the art, I infer that the electric light carbons found in commerce, and such as Dr. Morton states that he measured, were intended to be so plated.

The object of electro plating arc light carbons with copper being to increase their conductivity, it is evident that the amount of increase in this conductivity, or what is the same thing, decrease in resistance, will be proportional to the amount of copper which is deposited upon them. The Franklin Institute experiments of 1884 for example, showed that by plating the Buffalo carbons with 25.25 milligrams of copper per linear centimeter the specific resistance was reduced from 5725 to 1140 microhms as a mean, or from 6250 to 460 as a maximum; equivalent to a mean increase of conductivity of five times, and a maximum increase of 13.6 times, the original conductivity. The Brush carbons which were plated with 40.53 milligrams of copper to each linear centimeter have a mean specific resistance of 550 microhms, and a minimum specific resistance of 240 microhms; the specific resistance of the unplated carbon measured at the same time being 6490 microhms as a mean or 6910 as a maximum. So that the conductivity of these carbons may be assumed, I think, to have been increased twelve times as a mean, or twenty-nine times as a maximum, by thus electro-plating them. My own measurements are to the same effect; the specific resistance of Carre's electric light carbons tested by me falling to values varying from about 3700 microhms unplated to from 557.3 to 91.5 microhms, according to the amount of copper deposited upon them. Since, therefore, the low resistance which is required in carbons for arc lighting is readily obtained by electro plating them with copper, it is evident that the necessity of attaining this low resistance in the manufacture of the carbon rod itself is not important, and apparently has not been sought after.

Second, because he compares the specific resistance of arc light carbons which are *intended* to be plated with that of incandescent carbons which *are* plated.

From facts which have been already stated it appears that a carbon of high specific resistance may have its specific resistance greatly reduced by plating it with carbon. So that it would seem to me to be hardly a fair comparison to compare together arc light carbons intended to be plated but unplated, with incandescent carbons after they have been plated with carbon. This appears very decidedly, I think, from the statement given by defendant's witness, Mr. Vandegrift, in his deposition in this case; which is to the effect, I believe, that the specific resistance of the defendant's tamidine carbon would be about twice what it is now found to be if it were measured before being plated with carbon; and that the specific resistance of the carbon of defendant's M lamp and defendant's zigzag lamp would be increased in a very much greater ratio even than this if they were measured before the deposit of carbon was put upon them.

Third, because he compares the specific resistance of arc light carbons which have been subjected to a comparatively low heat with that of incandescent carbons which have been exposed to an exceedingly high one.

It is a well-known fact that the specific resistance of carbon is lower in proportion as the temperature is higher to which the carbon has been subjected. Since the temperature to which the carbon in incandescent lamps is subjected, while in the lamp, in the process of exhausting, is a very much higher temperature than the temperature to which it is exposed in the carbonizing furnace, it is evident that the specific resistance of such a carbon must be lower as measured in the finished lamp than the specific resistance which it has as it comes from the furnace; and as much lower as the temperature of the furnace was lower in which it was carbonized. It is a fact, I believe, that the decrease of the specific resistance of the same carbons on placing them in the lamp and heating them to the higher temperature required, over the resistance which these carbons possessed as they came from the furnace varies from 10 to 15 per cent. as a minimum in carbons which have been subjected to the highest furnace temperatures, to 50 or more per cent. as a maximum in the case of those carbons which have been subjected to lower furnace temperatures (which are yet regarded as suitable for the purpose). The furnace temperatures to which arc light carbons have been subjected in the process of manufacture are low temperatures, as I understand it, such as are comparable with those last mentioned; that is to say, are temperatures which are not very high as compared with those to which the filaments are subjected in the process of exhausting an incandescent lamp. It is obvious therefore, I think, that a comparison of the specific resistance of arc light carbons which have been heated to a lower temperature, with that of incandescent carbons, which have been heated to a very much higher one is not quite fair. A fairer one, it seems to me, would be to compare the specific resistance of the carbons of defendant's lamps with that of the electric light carbons measured by Dr. Morton after the specific resistance of these arc light carbons had been reduced probably by one-half, by subjecting them to an equivalent high temperature.

From a comprehensive consideration of the entire subject, however, I have reached the conclusion that if the filaments of defendant's lamps and arc light carbons are to be compared as to their specific resistances, a true result can only be obtained by comparing the former, either with the suitably dense and unplated arc light carbons of from 600 to 1000 microhms specific resistance, or with the plated arc light carbons of from 100 to 600 microhms specific resistance. The comparison will then be made with arc light carbons as they are intended for use. When judged by this proper standard of comparison, the filaments of defendant's lamps will be seen to possess, beyond a doubt, the characteristic of high specific resistance.

5 Q. What, in a general way, is the reason why arc light carbons have been plated with copper or other metal?

A. The first form of carbon which was used for the purpose of arc lighting was wood-charcoal employed by Davy in 1810. But this form of carbon was unsatisfactory owing to its rapid combustion, and in 1844 Foucault substituted for it the very dense carbon obtained by the distillation of coal and which is known as gas-carbon. This form of carbon also has its disadvantages, and therefore, a variety of processes came into use subsequently which had for their object to lessen the cost and to increase the uniform quality of carbon rods for arc lighting purposes. These processes in general made use of finely divided carbon mixed with a solution of sugar or with tar to a thick paste, this paste being molded into sticks and then carbonized in a furnace. In order to increase the density, and therefore the conductivity of the carbon rod thus made, the sticks were immersed in a solution of sugar or other equivalent solution and were rebaked; this process being repeated several times. It does not appear, however, that the conductivity attainable in this way was sufficiently high for arc lighting purposes: or that it was as high, in fact, as that of the gas-retort carbon which had been before used. This gas-retort carbon according to its compactness had a specific resistance as low as from 600 to 1,000 microhms in the best examples of it, while that of the so-called agglomerated carbons was not below 2,000 or 3,000 microhms, apparently. With the great increase of arc lighting about 1877 it became necessary to secure higher conductivity in the arc light carbons, as well as to protect them from too rapid combustion; and for this purpose several experimenters about the same time suggested the use of a coating of copper or other metal electro-plated upon these carbons. This process of electro-plating carbons enabled the low specific resistance required by the needs of arc lighting to be readily and economically obtained; and that independently of the specific resistance of the carbon rod before plating; carbons of any conductivity desired being readily produced by plating them with a sufficiently thick layer of copper. This suggestion was at once accepted and came into general use, so that, as I have before said, practically all the carbons in use for arc lighting at the present day are copper plated.

CROSS-EXAMINATION BY MR. DUNCAN:

6 x-Q. Do you wish to be understood by the testimony you have given to-day that you still maintain the views expressed by you on your former examination in this case in regard to the meaning of the term "high resistance," as used in the patent in suit?

A. As I understand the question, I do.

7 x-Q. Is it not a fact that at the date of the patent in suit there was a wide range in the specific resistances of the carbons that were used for arc lighting?

A. I suppose that there was a considerable variation in the specific resistances of arc-light carbons at the time referred to.

8 x-Q. Is it your understanding that the old carbons with which the patent in suit compares the Edison carbon, in the matter of specific resistance, were carbons that had been made for arc-lighting, but were used in incandescent lamps, or were they carbons made specially for incandescent lamps?

A. I think that I should say that some of the "rods of carbon" used in the older lamps of which the patent speaks, although they were made of the same materials and by the same process substantially as that by which arc-light carbons were made, were made of smaller diameter than the arc-light carbons, in order to adapt them for incandescent or semi-incandescent use.

9 x-Q. You have referred in your present testimony to the Sawyer & Man Patent No. 211,262, and have compared the defendant's carbons with Sawyer carbons assumed by you to have been made under the said patent. Please give the length and diameter of those carbons?

A. These carbons varied somewhat, both in diameter and length. They would average, I should say, about 1.15 millimetres in diameter, and from seven to ten centimetres in length.

10 x-Q. What was the diameter of the core of Carré carbon in these Sawyer carbons after the shell was removed?

A. As I recollect it, about three-quarters of a millimetre.

11 x-Q. How did you separate the shell from the core in those Sawyer carbons?

A. In some of the specimens the adherence between the shell and the core was so slight as to permit the removal of the shell mechanically—of course using sufficient care in the process to preserve the core intact.

12 x-Q. In view of the small size of these Carré carbons used by Sawyer as cores for his carbons, for what purpose do you understand them to have been originally made?

A. That I do not know, as a matter of fact, since I understand that these small carbons were used for other purposes than electric lighting. It is possible, of course, that they may have been made for electric lighting.

13 x-Q. Do you not think it probable that they were made for electric lighting?

A. If they were made to special order for Mr. Sawyer, I think it is probable.

14 x-Q. If they were not made on a special order from Mr. Sawyer, do you not think it probable that they were made for electric lighting?

A. If carbons of this size were made and kept in stock by the Carré Company at this date then it seems to me probable, in the absence of any evidence to the contrary, that the largest demand for such carbons might be for experimental electric light purposes.

15 x-Q. Do you know of carbons as small as these cores used by Sawer ever having been used for arc lighting?

A. I do not.

16 x-Q. What was your object in referring to these Sawyer carbons in your direct testimony, or to the Sawyer & Man Patent No. 211,262; was it because you considered that the patent in suit designed to include such carbons as these Sawyer carbons among the carbons of the prior state of the art with which it contrasts the carbon of the patent in the matter of specific resistance?

A. Reference to my direct testimony will show, I think, that the Sawyer carbons were referred to in one of a series of statements to illustrate the specific resistance of carbon given in my second answer.

17 x-Q. Did you also refer to the Sawyer carbons, and to the said Sawyer & Man patent under the impression that the said carbons were included in the prior state of the art referred to in the patent in suit when it contrasts Mr. Edison's carbon in the matter of specific resistance with carbons that had preceded it?

A. I do not remember to have had that precise idea in mind at the time of making the answer referred to. Inasmuch as the said Sawyer & Man patent was issued in January, 1879, however, it must have been known to Mr. Edison, and the Sawyer lamp may have been one of the old lamps referred to in the patent in suit; but, of course, I do not know this as a matter of fact.

Adjourned for lunch.

Resumed.

18 x-Q. How many of these Sawyer carbons did you get from Mr. Wallace?

A. I did not count them, but I should say a dozen or more.

19 x-Q. Have you made a pretty thorough search into the literature of electric lighting in order to ascertain the specific resistance of the various carbons used at various times?

A. I have, of course, examined the literature on the subject, but I cannot say that my investigations have been exhaustive.

20 x-Q. Did you not, in your search, find mention of many carbons having a higher specific resistance than those which you have specially named in your direct examination?

A. I did find carbons mentioned whose resistance was higher than that given in my direct examination.

21 x-Q. Did you find many such?

A. Yes, a good many.

22 x-Q. And, as I understand you, you selected for comment those carbons having the lowest specific resistance because you hold that Edison in speaking in his patent of the high specific resistance which his carbons were to have intended to compare his carbons with those older carbons which had the lowest specific resistance. Am I right in this understanding of your views?

A. The real reason, I think, why I gave the instances of the low specific resistance of carbon in my direct examination was that the question asked whether I still adhered to the position taken in my *prima facie* deposition, that "the high specific resistance called for by the first claim of the patent in suit is a specific resistance higher than that of some of the carbons used for electric lighting before the date of the patent in suit." In answering the question, therefore, I naturally gave examples of carbons having a low specific resistance.

23 x-Q. Is it not a fact that in your investigation of this question of specific resistances, you found a good many electric-lighting carbons having a higher specific resistance than that of the two lowest of the three lamps of the defendant?

A. I found that wood charcoal was one of the forms of carbon which had been used in electric lighting; and inasmuch as the specific resistance of wood charcoal depends upon the variety of wood used, as well as the temperature of carbonization, I think it probable that the specific resistance of this wood charcoal may have been higher than that of the lamps referred to.

I found also that carbons had been made for electric lighting which were very loosely aggregated, and were correspondingly porous, judging from their density. These carbons too might have had, I think, a specific resistance as high as and perhaps higher than that of the lamps referred to.

Since arc-light carbons, before baking, are practically non-conducting, it seems to me that they may have any resistance, after baking, up to the maximum theoretically attainable, according to their state of aggregation.

24 x-Q. As I understand the drift of your testimony on this subject of the specific resistance of carbons of incandescent lamps, such carbons will have the "high resistance" (by which I understand you to mean high *specific* resistance) of claim 1 of the Edison patent in suit, when their specific resistance is higher than that of *some* of the carbons which had been used in electric lighting before Mr. Edison's invention, even though it be lower than that of others of the carbons which had been so used. Does this correctly state your position?

A. I do not think that my opinion upon this question has changed materially since my *prima facie* deposition. I there said: (1) "The filament of carbon of the first claim should be a filament of carbon of high specific resistance. But I do not understand that this resistance is necessarily higher than that of any of the carbons used in the older incandescent lamps." I also said: (2) "In my opinion, it is essential that the filament of carbon of high resistance of the first claim be made of carbon having a higher specific resistance than that of some of the carbons previously in use for arc lighting." The word "any" in the first quotation above given is used in the sense of "all."

Adjourned until Wednesday, July 2, 1890, at 11 A. M.

New York, July 2, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

Cross-examination of the witness, George F. Barker, continued:

25 x-Q. By this I understand you to answer my last question in the affirmative; did you so intend?

A. That was my intention.

26 x-Q. As I recollect your former deposition, you were unable to state what absolute specific resistance a carbon must have in order to give it the "high resistance" which is an element in claim 1 of the patent in suit. Can you now state what absolute specific resistance a carbon must have in order that it may possess the quality of "high resistance" spoken of in the first claim of the Edison patent?

A. Unlike the metals, the range of variation in the specific resistance of carbon is very great. While, for example, the absolute specific resistance of silver or copper may vary five or six per cent., perhaps the absolute specific resistance of carbon may vary, according to the data given in my direct testimony, by 1,000 or more per cent. Where within these wide limits the line is to be drawn between high resistance and low, in the absolute sense, I cannot say; first, because the question seems to be a legal question, properly determinable only by the Court; and second, because I have no experimental data which will enable me to determine the limit where the special advantages secured by the use of this high resistance would cease to exist.

27 x-Q. Now, in view of the opinion expressed by you in your last answer but one, that the condition of "high resistance" (which you say means high specific resistance), contained in claim 1 of the Edison patent, requires that the specific resistance of the carbon used shall be higher than that of *some* of the old carbons

that preceded Edison's invention, though not necessarily as high as that of others of such old carbons, and in view of your inability, as admitted in your last answer, to state what absolute specific resistanse is required in order to bring a carbon within the conditions of the claim, how would you be able to say, with reference to any given specimen of carbon whose specific resistance is higher than that of some of the old carbons, but not as high as that of others, that it possesses the high specific resistance which is one of the essential elements of the said claim?

A. I do not see that there is any particular difficulty in the matter, in the present case, since it does not seem to me that the lines are to be drawn very narrowly. My opinions upon this matter are set forth pretty fully in my *prima facie* examination; I there stated that, "The high resistance of the first claim refers to a 'carbon of high resistance,' *i. e.*, to carbon (in a filamentary form) such as is produced by the well-known process of carbonization, and which, as compared with the varieties of carbon used in the only kind of electric lighting in commercial use at the date of the patent (arc lighting) has a high resistance." Since the carbons of defendant's lamps, for example, were made "by the well-known process of carbonization," and since, "as compared with the (most suitable) varieties of carbon used in the only kind of electric lighting in commercial use at the date of the patent (arc lighting), these carbons have a specific resistance five or six times as high, it seems to me that I was entitled to say that the carbon of these lamps of defendant is a "carbon of high resistance," in the sense in which this term is used in the first claim of the patent in suit.

27½ x-Q. Your argument proceeds upon the assumption, among other things, that the best varities of carbons used for commercial arc lighting prior to the invention of the patent in suit, had a specific resistance of only one-fifth or one-sixth of that of defendant's carbons. What is your warrant for this assumption?

A. It will be conceded, I think, that "in case of the arc lamp, the resistance of the carbon or other conductor cannot be too low, and all efforts have been directed to the end of securing the lowest possible resistance, consistent with the avoidance of drawbacks from other effects"; and also that "in an arc lamp, conductors which have absolutely no resistance would be ideally perfect." That is to say, as I understand it, that the "most suitable varieties" of carbon for arc lighting are those which have the lowest attainable specific resistance.

It will also be conceded, I think, that the variety of carbon known as "gas carbon" was used as the material of the rods or pencils for arc lighting. So that it seems to me that the conclusion in my last answer is equivalent to the statement made yesterday in my direct examination, as follows:

> "To illustrate what I mean, I may refer to the fact that the specific resistance of carbons used before the date of the patent in suit in electric lighting appears to have been as low as 600 microhms; while the specific resistance of the carbon filaments of defendant's lamps varies from 3,800 to over 6,300 microhms; thus showing that the specific resistance of these filaments is at least from 6 to 10 times greater than the specific resistance possessed by carbons which were actually employed for electric lighting before the date of the patent in suit."

28 x-Q. Do you mean to assert as matter of fact that the best varieties of carbon actually used commercially for arc lighting, prior to the date of the Edison invention in controversy, had a specific resistance as low as 600 microhms?

A. My understanding of the matter is simply this:

First, that the most suitable varieties of carbon for arc-lighting are those having the lowest specific resistance.

Second, that "gas carbon" was used in commercial arc lighting before the date of the patent in suit.

Third, that "gas carbon," as measured by Fontaine in 1877, had a specific resistance of about 600 microhms.

Fourth, that therefore the most suitable variety of carbon used in arc lighting before the date of the patent had a specific resistance of 600 microhms.

Adjourned for lunch.

Resumed.

29 x-Q. In your last answer you say that the most suitable varieties of carbon for arc-lighting are those having the lowest specific resistance, and from this general premise you draw the conclusion that "gas-carbon," which, according to the measurement of some specimens, has a low specific resistance, is the best kind for arc lighting. Now, do you not know it to be a fact that the specific resistance of the carbon is only one of the elements to be considered in selecting the variety to be used for commercial work, and that there are other qualities to be considered, notably, uniformity of texture or homogeneity, by reason of which the "gas-carbon" proved practically to be very poorly suited for arc-lighting, having had but an extremely limited use in this direction, and having, many years ago, been wholly discarded for this purpose?

A. It seems to me clear that a low total resistance is the most important requisite of an arc-light carbon. It seems to me also that low specific resistance is the important element in securing low total resistance. So that I should say, I think, that, other things being equal, the most suitable varieties of carbon for arc-lighting are those having the lowest specific resistance, such as the gas-carbon referred to.

Moreover, as I understand the matter, all the varieties of carbon used for arc-lighting have some disadvantages, as I pointed out in my fifth direct-answer. So that while it is true that, even at the date of the patent in suit, probably, a larger number of the molded carbons were in use than of carbons sawn from the deposit found in gas retorts, yet I think that the reason for this is to be found in the fact, 1st: That the process of sawing these hard and dense carbons made them expensive; 2d: That it was difficult to secure in this way the considerable length required in protracted lighting; and, 3d: That the amount of available arc-light carbons securable in this way was limited, compared with the growing demand, rather than in the fact that gas-carbon was *per se* unsuitable, as compared with the molded carbon.

It is my judgment, further, that the conferring of the necessary low resistance required, upon molded electric arc-light carbons by the process of electro-plating with copper was a most important factor in bringing these carbons into general commercial use, since thereby a carbon pencil of the same low resistance could be produced at a much cheaper rate.

30 x-Q. Is it not a fact that the Carré molded carbons had come into quite extensive use for arc-lighting before the process of metal-plating the carbon was devised?

A. My impression is that it is not. The patent of Carré was not issued until 1876. But processes of combining carbon with metals in various ways, in order to increase its conductivity for arc-lighting purposes, had already been patented by Staite in 1848, by Binks in 1853, by Harrison in 1857, by Carré himself in 1867, and by Reynier in 1875. Moreover, it is a well known fact that early in 1879 Siemens produced electro-plated carbons for commercial use. And Mr. Dredge says in his book on electric illumination, published in 1882, in speaking of the Carré carbon: "The Société Générale E'lectricité (the society exploiting the Jablochkoff candle) alone has consumed over three million metres or nearly 1,900 miles of these carbons." And he tells us further that: "A large number of the Jablochkoff candles are electro-plated, which makes them more durable, but at a certain expense of steadiness and uniformity of color. In many cases, and especially where industrial lighting is concerned, economy is the first point to be considered; since the month of August, 1879, when the process of galvanizing the carbons was practically introduced, four-fifths of the total production have been thus coated."

Adjourned until Thursday, July 3d, 1890, at 10:30 A. M.

NEW YORK, July 3, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, GEORGE F. BARKER, CONTINUED:

31 x-Q. Do you know of any instance prior to the date of the patent in suit in which the light-giving portion of the corbon burner of an incandescent lamp was plated with copper or other metal?

A. I do not.

32 x-Q. I presume, then, that you have no good reason for thinking that any of the earlier incandescent lamps referred to in the patent in suit made use of metal-plated carbons?

A. I do not recollect that the light-giving portion of the burners of the early incandescent lamps was electro-plated with metal, and hence I do not know that this portion of the earlier incandescent lamps referred to in the patent was so plated.

33 x-Q. In your direct testimony you refer to the measurements which you have made of the specific resistance of certain carbons. Have you tested other carbons than those about which you thus testified?

A. I have.

34 x-Q. Did you find the specific resistance of those other carbons, or any of them, to be higher than that of the carbons which you selected for reference in your direct testimony?

A. I did.

35 x-Q. Do you remember whether any of the carbons tested by you had a resistance as high as 4000 microhms?

A. My recollection is that some of the arc-light carbons which I measured had a specific resistance as high as this.

36 x-Q. You have referred in your direct testimony to the measurements of electric light carbons made under the auspices of the Franklin Institute Committee in 1884 Will you kindly give the specific resistance in microhms of the various carbons which were the subject of those experiments?

A. From the Report of the Committee of the Franklin Institue there appear to have been twenty-nine specimens of carbon measured. Their respective resistances were as follows:

WALLACE CARBONS (PLAIN).

No. 1.	Specific Resistance	4,800	microhms.
" 2.	" "	4,400	"
" 3.	" "	4,700	"

WALLACE CARBONS (COPPERED).

No. 4.	Specific Resistance	4,400	microhms.
" 5.	" "	3,100	"

BUFFALO CO. CARBONS (VITRIFIED).

No. 1.	Specific Resistance	5,000	microhms.
" 2.	" "	6,600	"
" 3.	" "	6,100	"

BRUSH CARBONS (PLAIN).

No. 1.	Specific Resistance	6,100	microhms.
" 2.	" "	6,230	"
" 3.	" "	6,720	"
" 4.	" "	6,910	"

BRUSH CARBONS (COPPERED).

No. 1.	Specific Resistance	1,080	microhms.
" 2.	" "	330	"
" 3.	" "	240	"

BUFFALO CARBONS (PLAIN).

No. 1.	Specific Resistance	6,250 microhms.
" 2.	" "	5,200 "

BUFFALO CARBONS (COPPERED).

No. 1.	Specific Resistance	2,210 microhms.
" 2.	" "	460 "
" 3.	" "	750 "

CORED CARBONS (PLAIN).

(These were hollow carbons surrounding a core of some different material.)

No. 1.	Specific Resistance	141,300 microhms.
" 2.	" "	170,000 "

CORED CARBONS (COPPERED).

No. 1.	Specific Resistance	422 microhms.
" 2.	" "	1,617 "

BOULTON CARBONS (COPPERED).

No. 1.	Specific Resistance	1,630 microhms.
" 2.	" "	2,180 "
" 3.	" "	475 "

CARRÉ CARBONS (PLAIN).

No. 1.	Specific Resistance	4,080 microhms.
" 2.	" "	3,770 "

It will be understood that these resistances in michroms are simply the resistances in ohms given in the second column of the table in the report of the committee. This assumes that the cross-section of these arc-light carbons was one square centimetre; which calculation shows to be practically the fact.

I think it should be observed that in this table there is a relation between the density of

a given make of carbon uplated and the amount of copper which is deposited upon this make of carbon in electro-plating it. Thus, for example, the density of the Wallace carbon is given in the same report as 1.571; that of the Buffalo carbon as 1.523; and that of the Brush carbon as 1.526; the amount of copper deposited upon these carbons, as it appears from this report, being 4½ millimetres for the Wallace, 25¼ for the Buffalo, and 40½ for the Brush per linear centimetre. These three varieties are all which are given in the table in both form plain and coppered. The vitrified and cored carbons seem to me anomalous, the latter for the reason given in the foot note.

37 x-Q. Where, as you understand it, did the Franklin Institute Committee, obtain the carbons involved in these tests of 1884?

A. The report of the Committee begins by stating, "Section VI., had submitted to it for inspection and report the carbons from five exhibitors, viz:

1. The Brush Electric Company.
2. The Wallace Carbon Company.
3. The Boulton Carbon Company.
4. The Buffalo Carbon Company.
5. The Carré carbons, manufactured by Emile Levy, Paris, and exhibited by Messrs. J. W. Queen & Co.

Of these the Brush, Wallace, and Boulton companies submitted plain and copper-coated carbons, the Buffalo Company a homogeneous carbon, both plain and copper-coated, and, in addition, a carbon with a core of pure graphite inserted in a sheathing of coke and a carbon with a vitrified coating, while Queen & Co., offered only the uncoated Carré carbons."

38 x-Q. Is it not a fact that, by reason of the lack of homogeneity and the presence of oxide of iron and other impurities in greater or less degree, different specimens of gas-retort carbon differ widely as to their specific resistance?

A. If by homogeneity be meant porosity and lack of compactness, then I should say yes in answer to the first part of the question. Moreover, the specimens of gas carbon deposited next to the walls of an iron retort are likely to be contaminated with oxide of iron from the retort which would increase their specific resistance. It should be bore in mind, I think, that moulded carbons, however, are largely made from pulverized gas-retort carbon.

39 x-Q. Have you found in the authorities any other statement besides that which you have given from Fontaine's work which puts the specific resistance of "gas-retort" carbon as low as that of the particular specimens which Fontaine professes to have tested?

A. The number of persons who have made measurements of the specific resistance of electric carbons is surprisingly few. Dr. Morton gives only three, and I have found only about as many more. But Marchand says that the density of "gas retort" carbon varies from 2.356 to 1.723, according as the specimen is taken nearer or more distant from the walls of the retort. So that if we may assume the specific resistance of "gas retort" carbon to be proportional to the density, this density would indicate a specific resistance below 2,000 microhms, I think.

40 x-Q. Have you any other authorities on the specific resistance of "gas retort" carbon?

A. I believe other experimenters have measured gas carbon, but none of them measured, I believe, varieties of gas carbon which had as low a specific resistance as those I have referred to.

41 x-Q. What are the measurments given by these other persons, as you have ascertained them?

A. I find that the only other measurements of "gas retort" carbon which I have noted are those of Beetz. In 1876 he measured such a carbon, which had a specific resistance of 3,274 microhms, and in 1881 he measured one having a specific resistance of 3,027 microhms.

Adjourned for lunch.

Resumed.

42 x-Q. When, in answer to question 2, you quoted from Prof. Farmer, as his statements are given in Prescott's book, did you do it under the impression that Prof. Farmer's measurements of arc light carbons took place at a time prior to Mr. Edison's application for the patent in suit?

A. It will be observed that Mr. Prescott's book, which is marked 1879 on the title page, was copyrighted in 1878, and my impression is that the measurements of carbon which Prof. Farmer made were made even before this.

43 x-Q. From what is this "impression" derived?

A. First, from the communication itself which Mr. Farmer made to Mr. Prescott, and which the latter incorporated into his book. He there states that he experimented with a platinum wire in 1859, and adds: "I tried various substances in the course of my investigation, such as copper, aluminum, platinum, iridium, palladium, iron, nickle, carbon, etc." He continues: "Since that time I have been almost continuously engaged in making further researches in this direction; have studied the conditions under which incandescent bars of carbon can be used in sealed globes, and have studied the construction of magneto-electric machines best adapted to this purpose."

Second, from my personal acquaintance with Mr. Farmer, and my knowledge of the fact that subsequently, especially after his removal to Newport, his condition of health was such that he was able to do but very little experimental work.

44 x-Q. When did he go to Newport?

A. I cannot say exactly, but my impression is that it was as early as 1873 or 1874.

45 x-Q. In answer to question 2 you quote Prof. Farmer (from Prescott's book) as saying: "The resistance of some specimen" (of arc light carbons) "which I have tested is about 1,500 or 1,600 times that of pure copper at 32 degrees."

Please state whether the sentence from Prescott's book, from which you make the foregoing quotation, does not contain the following additional words, immediately succeeding the word "degrees," to wit:

"While the specific resistence of other specimens is at least twice as great"?

A. I believe that is correct.

46 x-Q. State whether the entire communication of Prof. Farmer to Mr. Prescott, as printed in Prescott's book, is not in the following words:

"Since the foregoing was put in type we have received a very interesting communication from Mr. Moses G. Farmer, on the subject of electrical lighting, which we give herewith. Its importance in this connection is amply shown in the amount of general information it contains, and which Mr. Farmer's large experience renders him so eminently able to give.

In the summer of 1858, while reading of the very interesting experiments of Prof. Draper on the heat and light evolved by a platinum wire, which was traversed by an electric current, I was struck by the rapid increase in the amount of light given out as the temperature of the wire approached the point of fusion, and it struck me that, if the temperature of the wire could be steadily maintained quite near the melting point, a useful light could be obtained from it. I was not long in devising a combination of electro-magnets, rheostats and batteries that would give the desired result, and early in 1859 I put the idea into successful and practical execution, and we had a beautiful light in use in my house in Salem.

I at once entered upon a protracted investigation of the conditions which govern the management of the current, the construction of rheostats, the arrangement of lamp, &c., and the best proportion of length, width and thickness of the illuminator. I tried various substances in the course of my investigation, such as copper, aluminum, platinum, iridium, palladium, iron, nickel, carbon, &c.

"Pure iridium gave the best results of any of the metals. Alloys of iridium and platinum gave next best results, and next to this, platinum and palladium. Carbon, when inclosed in an atmosphere free from oxygen, also gave satisfactory results. Nitrogen, carbonic oxide and hydrogen are all suitable gases to surround the incandescent carbon. A vacuum is, perhaps, better, were it not for the difficulty of maintaining it.

The important point is, that the higher the temperature of the incandescent substance, the greater the amount of light; and it is very noteworthy, that it requires nearly half as much current to make platinum shine in the dark as it does to fuse the wire or ribbon. Three quarters of a fusing current will not give one-half the light that will be given off by seven-eighths of the fusing current. A flat ribbon of platinum will give nearly one hundred candle lights per square inch, if it be maintained within two hundred degrees Fahrenheit of the melting point, and I have been able to keep it at this temperature for hours and days. A bar of pure iridium, owing to its higher melting point, will give several times as much light as an equal and equally exposed surface of platinum; but, since pure iridium is neither malleable nor ductile when cold, it is costly to work it into convenient shape; hence, I have had recourse to alloys of platinum and iridium, which, although they do not give so much light as pure iridium, are yet superior to pure platinum. The platinum does not seem to waste perceptibly, yet I think I have detected a tendency to volatilization.

The resistance of platinum, at the melting point, is nearly seven times its resistances at thirty-two degrees Fahrenheit. A very simple empirical formula expresses the relation between the strength of current needful to melt, and the dimensions of the wire, and this formula serves as well for other "substances as for platinum, when the proper constants are supplied.

I found no difficulty in subdividing the current into as many branches as I pleased, and in maintaining as many lamps as I desired in each branch, provided I had at my control sufficient electromotive force and conductivity. I found that less than two hundred foot-pounds per minute would maintain one candle light, if the piece of platinum were of suitable form and dimensions. It was easy to supply current to any desirable number of branches, and to so adjust the regulator that, if one, two or three of the branches were removed or cut off, the supply of electricity would be so curtailed as to maintain, at the proper temperature, the lamps in the remaining branches.

My regulator, as I used it in 1866, 1867 and 1868, was so sensitive as to feel the current of air arising from the opening and shutting of a door of the room in which the apparatus was placed.

I had this apparatus on exhibition at 109 Court street, in Boston, during the years 1865, 1866, 1867 and 1868, until it was destroyed by fire. Since that time I have been almost continuously engaged in making further researches in this direction; have studied the conditions under which incandescent bars of carbon can be used in sealed globes, and have studied the construction of magneto-electric machines best adapted to this purpose.

There are four principal methods of producing electric light, on which I have bestowed much attention:

The first method is that in which an electric arc is maintained between carbon points. It is well known that a counter electo-motive force, or polarizing force, is encountered in the passage of the current between the electrodes, and this polarization is often as great in amount as twenty or thirty volts.

"The resistance to conductivity in the arc varies also, being less as the cross section of the arc increases, less as the temperature increases; also as the length of the arc diminishes, following the laws of conduction in fluids and liquids. With carbon one-quarter inch square, and a current of from twelve to twenty vebers, the resistance of the arc may be set down at ten to thirteen ohms per linear inch of arc, varying, however, between wide limits.

With carbon one-half inch square, and current of fifty or more vebers, it is much less. The best prepared carbon weighs more than an avoirdupois ounce per cubic inch.

The resistance of carbon, unlike that of metals, does not vary greatly with the changes of temperature. The resistance of some specimens, which I have tested, is about fifteen hundred or sixteen hundred times that of pure copper, at thirty-two degrees, while the specific resistance of other specimens is at least twice as great.

The light evolved is due in considerable measure to the oxidation of the carbon by the atmosphere. Much of the light is, however, due to the energy of the current, and this depends on the density of current in the arc.

A second method of producing electric light is by rendering a continuous bar of carbon incandescent in the air by the passage of a current of sufficient density to raise its temperature to a white heat. Here much of the light is due to the superficial oxidation of the carbon bar, and this may, perhaps, prove to be the most economical method of producing it.

The third method is by enclosing the carbon bar in a closed transparent globe, free from oxygen. In this case the carbon is not consumed, but the light is wholly due to the energy (RS^2) of the current acting on the bar.

The fourth method is that of rendering some of the metals, with high-melting points, incandescent by the passage of a current of great density.

"This is the method to which I have given most attention and which promises to be the most convenient for minutely subdividing and widely distributing electric light, especially for domestic illumination. An entirely new field for electric engineers is thus opened, in which our accumulated stock of knowledge will be most usefully employed.

Previous to my investigations, Gardiner and Blossom had experimented on and patented a signal lamp which was illuminated by a coil of platinum wire, heated by the passage of a current of electricity from a galvanic battery.

King, Staite and others had studied the use of carbon bars in sealed globes, and had proposed methods that would have been applicable and useful had there been any cheap and convenient source of electricity. I found that a current from a galvanic battery increased the cost of electric light to three or four times the cost of light from gas; and to remove this source of difficulty I turned my attention to the thermo-electric battery in 1864–5, just then being brought into notice by Marcus, of Berlin. I was, however, never able to utilize more than one three-hundredth of the energy possessed by a pound of coal in this form of electro-motor; and so, in 1865-6-7-8, I turned my attention to the perfection of a form of magneto-electric machine which I had conceived of in 1859—namely, one in which the current derived from the armature should maintain the field of force in which it revolved, and also perform the useful work in the external part of the circuit. I succeeded in 1866 in so far perfecting this apparatus as to be able to give some account of its performance to Mr. H. Wilde, of Manchester, England, in October, 1866, and an extract from my letter to him was published in the Manchester "Philosophical Magazine," if I recollect rightly.

From all my researches I conclude that when light is produced in large amounts—say five thousand, ten thousand, fifteen thousand candle lights—from one lamp, as much as eight hundred to twelve hundred candle lights can be obtained from the expenditure of one horse-power upon a suitable dynamo-electric machine and properly prepared and utilized carbon.

Now, while it is remembered that as much as two thousand or three thousand foot pounds of energy per minute per candle light is consumed in the production of light from ordinary illuminating gas, it will be apparent that a large field is opened, for the introduction and utilization of the electric light, which often requires the expenditure of less than one hundred foot pounds of energy per minute per candle light.

A great deal has been said and written about the difficulty of subdividing the electric light. Now, there is really no difficulty, except that which arises from inexperience and the lack of skill.

If a wire of pure platinum five inches long and one-hundredth of an inch in diameter be traversed by a current of electricity somewhat more than five and less than six vebers in strength, it can be maintained at a temperature quite near to the point of fusion, and while in this condition, it will, in the common atmosphere, emit something more than three candle lights, and just below the melting point the light will be between four and five candle lights.

If the light be enclosed in a glass globe and surrounded by hydrogen gas it will radiate less light. The resistence of the wire at the melting point will not be far from one and a quarter ohms if the platinum be pure; hence the energy active in the wire with a current of five and a half vebers (which it will ordinarily withstand) will not be far from $44\frac{1}{4} \times (5\frac{1}{2})^2 \times 1.25 = 1{,}673$ foot pounds per minute, and if it give four and a half candle lights, which it will do if the surface of the platinum be highly polished, we should require $\frac{1673}{4.5}$ = say 370 "foot pounds of energy per minute per candle light.

Now, if one hundred such wires be put in series in a circuit, the sum of this resistance would be one hundred and twenty-five ohms, and it would require a difference of potential equal to $125 \times 5\frac{1}{2} = 687\frac{1}{2}$ volts to maintain this strength of current of five and a half vebers and we should get in the aggregate five hundred or more candle lights.

If, further, we should arrange ten such circuits in multiple arc having one hundred lights in each of the ten branches, we should find the joint resistance of this part of the circuit reduced to twelve and a half ohms; but it would now require a current of fifty-five vebers' strength to keep the lamps all shining, and the difference of potential required to maintain the one thousand lights, each from three to five candles, would still be six hundred and eighty-seven and a half volts; but we should now have five thousand candle lights instead of five hundred, and the energy absorbed in this part of the circuit would be equal to $\frac{44.25 \times 12.5 \times 55^2}{33,000} =$ more than fifty horse power to maintain the five thousand candle lights or one hundred candle lights per horse power. But it must be remembered that this is not all the energy consumed in the production of the light; this is only the useful energy.

Besides this, there is the RS^2 consumed in heating the leading and distributing wires, also that consumed in the magneto-electric machines or whatever source be employed.

This may be represented by $B\,S^2$, wherein B represents the internal resistance of the electromotor, and can be made as small as one's purse will allow.

On this basis, let us suppose a city of five hundred thousand inhabitants to be furnished with electric light from platinum lamps, one of, say ten

"candles to each inhabitant. The aggregate amount of light would be five million candles; and if only one hundred candle lights were obtained from one horse power, we should then require fifty thousand horse power to furnish this amount of light, leaving alone the energy consumed in its production and distribution, which would, without doubt, exceed this amount, or nearly so, with the best machine now in use.

If you turn to the account of the experiments on the Brush light as executed at the Franklin Institute, you will find that the cost of the production was, on the average, in excess one three-hundredths of a horse-power per candle light; and this, too, with carbon points, and with light in greater amount than ten, fifteen or fifty candle lights per lamp. Now, it is well known that the greater the amount of light at any source, the greater the economy, and so a five or ten thousand candle light costs less per candle than does a ten, fifteen or twenty candle light.

If next we consider the incandescent carbon, in an atmosphere free from oxygen, as in King's, Staite's, Kosloff's and other lamps of this class, we shall find that a carbon rod three-eighths of an inch in length and one-thirtieth of an inch in diameter will offer a resistance of not far from half an ohm, whether it be cold or hot, and such a bar will bear a current of from ten to fifty vebers' strength for a time, without injury, and will give a soft, mild and very pleasant light, not too concentrated, but very desirable; and, as with the platinum lamp, many of those lamps can be put in one circuit, and many branch circuits in multiple arc can be heated simultaneously by one source of electricity, provided it have sufficient electro-motive force and conductivity, and the light will be more economical than from platinum, because the carbon, when thus protected, will withstand a higher temperature than will the platinum.

Next, we will consider the electric light produced "by the arc between carbon points. If we have two suitable carbon rods, each, say, five-sixteenths of an inch diameter, and separated to the distance of about one-sixteenth of an inch, and apply to these electrodes a source of electricity, which has an electro-motive force of, say seventy volts, and an internal resistance of, say three ohms, we shall, after establishing the arc, find a current developed of about eight or ten vebers, and a light produced equal to from one hundred to four hundred candle lights.

If the resistance (four ohms) of the circuit were all metallic, the current developed would be in amount equal to sixteen or seventeen vebers; but the electric arc behaves like an electrolyte, and offers a counter electro-motive force, and so the actual electro-motive force in the circuit may be thus represented; E——e, where E is the electro-motive force of the machine, and ——e the counter or polarizing force of the arc. If, now, l represent the resistance to conductivity of the arc, B, the internal resistance of the battery or machine, and r that of the leading wires, then the strength of current active in the circuit will be

$$C = \frac{E - e}{B + r + l}$$

The value of e varies, and all the conditions of its variation are not yet well understood. It is sufficient for our present purpose to know that it is sometimes as high as twenty or thirty volts, and that the resistance to conductivity in the arc is often as high as fifteen or sixteen ohms per lineal inch of arc, being much smaller when the light is very great, say when it is ten or fifteen thousand candles.

With this basis, suppose our magneto-electric machine or galvanic battery possesses an electro-motive force of seventy volts, and an internal resistance of three ohms, it will maintain an arc be-

"tween carbon points, and, with care, this arc can be made to exceed one-sixteenth of an inch in length if the carbons be of good quality. Now, let us construct a machine with one hundred and forty volts intensity, and with an internal resistance not much greater than three ohms, at least not so great as six ohms. We can now maintain two short arcs in series in this circuit, each giving considerable light. With careful manipulation, even three arcs could be simultaneously maintained with such a machine.

If, now, our electro-motive force were raised to or in excess of seven hundred volts, we might maintain, possibly, as many as ten arcs in one circuit; but the feeding mechanism of the lamps would need to be well constructed, accurately adjusted and rendered sensitive to slight variations in the strength of the current.

Suppose, further, that our machine has still an electro-motive force of seven hundred volts, but now its internal resistence is reduced to one-tenth of an ohm, I doubt not that five or more such circuits of ten lamps each could be run in multiple arc by the aid of this machine, as it is not probable that all the lamps in one branch would go out at once.

I have maintained three or four branch circuits in action at the same time, each branch having one lamp in it.

I find it much more difficult to run a few lights in each branch circuit than it would be to run several, if the construction of the machine be suitable, and the power ample, as the laws governing the strength of current in branch circuits show would happen.

To sum up, then, the electric light question, there are many good and well-known magneto-electric machines free to the public to use, for instance, the Saxton, the Siemens, Carpenter, Shepard and many others; then, too, there is the platinum lamp of Gardiner and Blossom; the incandescent carbon lamps of King, Staite and others.

"Besides these there are the carbon point lamps of Browning, Dubosque, Serrin, Siemens and many more, which are all free to the public, and hampered by no patents; no carbon point lamp need be better than the Serrin, when properly constructed, as it can be run for hours without flickering or going out, if the carbons be good, the lamp well made and properly adjusted, and if the machine which supplies the current be of ample power.

Light to the amount of from one hundred to one thousand candles per horse power can be obtained from some of these machines and lamps, while at best no more than twenty-five or thirty candle light can be obtained from one horse power's worth of gas.

So let me here repeat what I in substance published in the "Scientific American," a few years since, namely, that one pound of coal, if used for making gas, would yield enough to supply a candle light or its equivalent for about fifteen hours.

One pound of the gas, when made and burned, yields a candle light for seventy-five hours. Further, one pound of coal, burned in a good furnace under a good boiler, will furnish sufficient steam to drive a good steam-engine, and a magneto-electric machine, for a sufficient length of time, to furnish an electric light, which in intensity and duration shall be the equivalent of one candle light for one thousand hours.

But if all the energy locked up in one pound of carbon could be liberated and converted wholly into light it would be equivalent to that given by one candle during one and a half years, if all concentrated in one source.

Hence, let experimenters take courage, and try to fill this chasm between one thousand hours and one and a half years!

When we shall see the electric light distributed in our dwellings it may prove a source of pride to

"Salem to call to mind that this boon met its first success in that city, where a parlor, in Pearl street, was lighted every evening during the month of July, 1859, by the electric light, and was undoubtedly the first private dwelling-house ever lighted by electricity.

A galvanic battery furnished the electric current, which was conveyed by conducting wires to the mantel-piece of the parlor, where were located two electric lamps. Either lamp could be lighted at pleasure, or both at once, by simply turning a little button.

This light was soft, mild, agreeable to the eye, and more delightful to read or sew by than any light ever seen before. It was discontinued, for the reason that the acids and zinc consumed in the battery made the light cost about four times as much as an equivalent amount of gaslight. Now that we can have cheap electricity from the dynamo-electric machine we may soon expect better things of it.

A word as to the cost of electric light as compared with light from gas. Perhaps on the average one pound of illuminating gas will give seventy-five candle lights per hour. One pound of illuminating gas posseses a sufficient store of energy to enable it to give out, by combustion, about twenty thousand units of heat, or the equivalent of about sixteen million foot pounds of work. This, if burned in an hour, would average about two hundred and fifty thousand units of work per minute, or about thirty-five hundred foot pounds per minute per candle light.

A very large electric light, say ten thousand candles, does not consume more than twenty foot pounds of energy per minute per candle light, and even a small electric light of twenty candles need not consume more than two hundred foot pounds per minute per candle light. So it might not seem extravagant to expect that one pound of gas per hour could be burned in a suitable furnace "under a proper boiler, and steam be taken from the boiler to a steam engine to drive a magnetic electric machine, which should supply five electric lamps that would give more light than five gas lamps, each consuming one-fifth of a pound of illuminating gas per hour."

A. Yes.

Re-direct Examination by Mr. Dyer:

47 Re-d. Q. In the cross-examination of Professor Morton, there appear the following question and answer, taken from his direct examination in the McKeesport case:

> "27 Q. Aside from low specific resistance, what is the quality particularly requisite in arc-light carbons?
>
> A. Resistance to combustion, or, in other words, what we may describe as hardness, in this connection. In other words, an extreme density, by reason of which, even at very high temperatures, the chemical action of the air can have only a minimum effect upon the electrodes."

What relation, if any, exists between the specific resistance of carbon and its hardness, or density, or resistance to combustion, referred to as equivalent characteristics in the answer given by Dr. Morton?

A. The specific resistance of carbon depends inversely upon its state of aggregation, the resistance being higher, of course, as it is more loosely aggregated. The density of carbon depends directly upon its state of aggregation, and is the greater as the state of aggregation is greater. So that the density of a specimen of carbon would be increased in proportion as the amount of matter in a given volume is increased; in other words in proportion as it is more compact and less porous. So that the specific resistance of a specimen of carbon depends upon the same condition as the density (although inversely), to wit, upon its compactness or

the closeness with which the particles are aggregated together.

Moreover, since the carbon particles themselves are exceedingly hard, a closely aggregated specimen of carbon would evidently be, for this reason, a specimen possessing a high degree of hardness. "Resistance to combustion" I understand to be equivalent to slowness of combustion; and this also is dependent upon the compactness. So that a dense, compact and hard carbon would, I think, have for this reason a low specific resistance, and would burn with proportionate slowness; in other words, would offer a high resistance to combustion.

George F. Barker.

Adjourned until Tuesday, July 8, 1890, at 11 A. M.

New York, July 8, 1890.

Met pursuant to adjournment.

Present—R. N. Dyer, of Counsel for Complainant; R. H. Duncan of Counsel for Defendant.

John W. Howell, a witness produced on behalf of the complainant, being duly sworn, deposes and says, in answer to questions by Mr. Dyer, as follows:

1 Q. What is your name, age, residence and occupation.

A. John W. Howell, aged, thirty-two. Occupation, Electrician of The Edison Lamp Company. Residence Newark, N. J.

2 Q. How long have you been connected with The Edison Lamp Co., and what are your duties?

A. I have been connected with the Edison Lamp Co., as electrician nine years. During this time I have had charge of the testing of all lamps made, also a general oversight of all processes in the factory, in which the electric current is employed; also, for the last five or six years I have had charge of the indicator department, where the indicators used by the Edison Company are made. During the whole nine years I have also done work outside of the factory as a general expert on the Edison central station system.

3 Q. Are you acquainted with the patent in suit No. 223,898?

A. Yes, I am.

4 Q. Have you lately constructed lamps in accordance with the specifications and drawing of the patent in suit, and more especially lamps with filamentary carbon burners made of the tar and lamp-black composition described in the patent, secured to platinum wires or tips before carbonization, and made in the form of a spiral, in accordance with the specifications and drawing?

A. Yes, I have. During the months of March and April of this year, I made a number of lamps as indicated in the question, the lamps being made strictly in accordance with the specifications and drawing of the patent in suit. I hereby produce the lamps, and a tabulated statement showing the lamps by number, the same numbers appearing upon the lamps themselves. This statement also gives the dimensions, before carbonization, of the filaments, their form, the candle-power at which they were tested, the volts, amperes, watts per candle, and resistance at this candle-power, also their cold resistance.

The tabular statement referred to by the witness is offered in evidence by Counsel for Complainant, and the same is marked, Complainant's Ex. Howell's Statement No. 1.

Witness continues: I also produce another tabular statement showing the number of filaments made on the dates given, the number of good lamps produced from them, and what became of the remaining filaments.

The statement just referred to by the witness is offered in evidence by complainant's counsel,

and the same is marked Complainant's Exhibit Howell's Statement No. 2.

Counsel for complainant also offers in evidence the box of tar-putty filament lamps referred to by the witness, the same containing twenty-six lamps, corresponding with the number shown by Complainant's Exhibit Howell's Statement No. 1; and the same is marked Complainant's Exhibit Howell's Tar-putty Lamps.

5 Q. Please describe the various steps of manufacture which you followed in the production of these tar-putty lamps?

A. The lamp black used in the manufacture of these lamps was made in our factory. The coal tar I obtained from one of the gas-works in Newark. The coal tar was used just as it came from the gas-works, while the lamp black was calcined as described in the patent in suit. The lamp black and tar were then mixed and kneaded thoroughly, until they had the consistency of thick putty, care being taken to incorporate the two thoroughly together. Pieces of this tar putty were then rolled upon a plate of ground glass by a narrow stick, until it made a long piece, forty or fifty thousandths of an inch diameter. A small piece of this was then cut off and rolled upon the glass by the same stick, until it was from six to seventeen thousandths of an inch in diameter, in different pieces. Pieces were then cut off five inches long. Small pieces of platinum were attached to the ends of these pieces by means of the same tar and lamp black mixture. These pieces with the platinums attached were coiled upon a wooden mandrel to make spirals. These spirals were immediately slipped off of this wooden mandrel, upon a carbon support very much smaller in diameter than the wooden mandrel. These carbon supports, with the spirals on them, were put in a frame, so that the platinum wires upon the ends of the spirals were supported so their weight did not drag upon the spirals.

The spirals, still upon the supports, were packed in powdered plumbago, and carbonized. Some of these spirals were dried in an oven at a temparature of 200°

Fahr., then slipped off the supports, and packed in plumbago, and carbonized. Lamps numbered 1–18 were made in this way.

Lamps numbered 19–26 were made in precisely the same way, up to the point of winding on the mandrel. These lamps were coiled between a helix of copper wire, supported and dried as the others first mentioned were and carbonized in the same manner, the copper wire being afterward eaten off by nitric acid.

All these carbons were then mounted upon glass holders, and glass bulbs were blown over the whole with a leading-tube for exhaustion by mercury pump. They were then exhausted as described.

Lamps 27–31, instead of being coiled upon a mandrel to make spirals, were made in the form of a loop, or hairpin. These filaments, with the platinums attached, were hung over a piece of arc-light carbon, the ends of the loops, with the platinums attached, hanging downward from the arc-light carbon, without any other support. In this position they were dried at 200° Fahr. for two hours, then taken off the arc-light carbon, packed in plumbago and carbonized, without any support except the plumbago.

6 Q. If you have prepared an exhibit of the tools employed by you in the preparation of the tar-putty filaments, please produce and explain the same?

A. I have prepared an exhibit of the tools used in the manufacture of these tar-putty filaments, and hereby produce it. The piece of ground glass upon which the tar-putty was rolled is numbered 1. The stick with which all these filaments were rolled is numbered 2. The wooden mandrel upon which the filament of lamps numbered 1–18 were coiled is numbered 3. The smaller carbon supports upon which these spirals 1–18 were carbonized are numbered 4, 5 and 6. The frame upon which some of these spirals, with their supports, were placed during carbonization is numbered 7. Numbers 8 and 9 are filaments carbonized between the coils of a copper helix, the carbons and helices both being shown just as they came from the carbonizing furnace. No. 10 is a carbon from which a copper wire helix has been eaten by nitric acid. No. 11 is a tool for holding these copper wire helices and winding the filaments upon them, a filament partly wound upon a copper wire helix being shown in connection with this tool. Nos. 12 and 13 are carbon boxes in which the filaments were packed during carbonization.

These boxes with their contents were placed in ordinary graphite crucibles, packed in plumbago and carbonized in a gas furnace for one hour, care being taken to keep the temperature below the melting point of copper. No. 14 is a cover used with one of these boxes. No. 15 is the piece of arc-light carbon upon which the loops were dried. Nos. 16, 17 and 18 are pieces broken from loops made as described. Nos. 19, 20 and 21 are tar-putty filaments which were made with the tools in this exhibit and which are seven-thousandths of an inch in diameter and over a foot long.

The frame, No. 7, is made of copper, and in it is shown a spiral coiled between a helix of copper wire in the position in which those carbonized in the frame were carbonized.

Counsel for complainant offers in evidence the exhibit referred to by the witness, and the same is marked Complainant's Exhibit Howell's Tools.

7 Q. What was the character of the carbonizing furnace you employed, also the character of the drying oven you have mentioned? And why was the latter used in some instances?

A. The gas furnace which was employed was an ordinary assayer's gas furnace, made by the Buffalo Dental Manufacturing Company and purchased from Eimer & Amend. The drying oven consisted of an ordinary wooden starch-box, with a horizontal glass partition dividing it into two parts. Beneath the glass partition, on the bottom of the box, was an incandescent lamp, which was the source of heat. The filaments to be dried, with their supports, were placed upon the glass partition, the top of the box being closed by a newspaper. This was used to obviate the necessity of heating the filaments slowly in the carbonizing furnace. The furnace was not adapted for bringing up a slow heat, frequently going out when the gas was turned down low. By drying the filaments in this box they could be brought up to a high heat immediately in the carbonizing furnace.

8 Q. State whether or not you consider the various processes and implements or tools employed by you in the manufacture of these tar-putty filament lamps such as are described in the patent in suit, or such as would have been employed by a skilled workman at the date of the patent in suit after having read that patent?

A. I do consider the processes and implements employed by me in the manufacture of these tar-putty filament lamps such as would have been employed by a skilled workman at the date of the patent in suit after having read that patent. When I undertook to make these lamps I placed myself as far as possible in the position of the man described in the question, and I have endeavored, and, I think, successfully, to exclude all processes and tools which were not well known at the date of the patent in suit, and not suggested either by the specifications or by the processes named in the specifications, which processes were well understood at the date of the patent.

9 Q. Have you with you a sample of the tar-putty such as you employed in the manufacture of these lamps?

A. I have, and hereby produce a bottle containing three pieces of tar putty of the same lot from which most of the lamps exhibited were made.

Complainant's counsel offers in evidence the bottle and its contents referred to by the witness, the same being marked "Complainant's Exhibit Sample of Tar Putty."

Adjourned for lunch.

Resumed.

10 Q. In addition to the tests shown by your statement No. 1, have you had made any other tests of these lamps such as a test showing the life or the durability of the lamps. If so, what were these tests, and what were their results?

A. Yes; I did make a life test on a number of the lamps included in this exhibit. Lamps Nos. 2, 3, 5, 9, 13, 14, 15 were sent to the Edison Laboratory, at Orange, to be tested for life. These lamps were set up at a candle power giving 6.2 watts per candle. This is equivalent to producing 7½ sixteen-candle lamps per horsepower. These lamps were put up and maintained at a constant potential for 600 hours. Lamp No. 5 was defective when set up, having a bad vacuum. This lamp immediately deteriorated, as was shown by its noticeable dulness, immediately after it was set up. It broke in three or four hours, the carbon being oxidized.

The other six lamps burned 600 hours without any further breakage. This life test was stopped at the end of 600 hours, as that is the life which all lamps are guaranteed to give, as an average, and any lamp which will give this life is a practical and commercial lamp. Another reason for taking them down at the end of 600 hours was to enable me to produce them here to-day, the 600 hours having expired only July 3d.

In addition to the test for life, the candle-power of the lamps was tested four times during the 600 hours run, to show the rate of deterioration of the lamps. The ability of a lamp to maintain a uniform candle power is a feature of very great value, and goes as far as anything else in determining the commercial value of a lamp. At the end of 62¼ hours these lamps gave 94.96% of their original candle power. At the end of 182¼ hours they gave 90.62% of their original candle power. At 355¾ hours they gave 92.70%, and at the end of 600¾ hours they gave 85.00% of their original candle power, all these measurements being made at the potential at which the lamps were set up, and had always been burned.

11 Q. Do you consider the depreciation in candle power shown by the candle power tests which you have just stated, a favorable or an unfavorable showing for the commercial utility of these lamps?

A. I think it an extremely favorable showing, and a far better one than I anticipated when the lamps were set up. In fact it is a remarkably good showing. The results of this test, both in life and in candle power, show that tar putty is a very good material for making carbon filaments.

12 Q. How does the efficiency (number of 16-candle lamps per horse power) at which you tested these lamps, compare with the efficiency of the first bamboo-carbon lamps made and sold as a regular commercial article by the Edison Lamp Co.?

A. The first regular commercial bamboo-carbon lamps made and sold by the Edison Company gave about seven 16-candle power lamps per horse power. These tar putty lamps, being tested at the rate of $7\frac{1}{2}$ 16-candle lamps to the horse-power, were tested at a higher efficiency than the first commercial bamboo lamps before mentioned. The reason for testing these lamps at the above-mentioned efficiency was to determine their value under conditions which were commercial at the date of the patent in suit.

13 Q. The witness, Elihu Thomson, who testified for the defendant, expressed the opinion in his eighth answer that a lamp made after the specifications and drawings of the patent in suit, with a carbon burner made from a wire of tar putty coiled into a spiral and united to the platinum wires before carbonization, would not be a practicable or a serviceable lamp. As his first reason he says:

> "We have as an obstacle the difficulty of producing such a thin, uniform thread of tar-putty as is described in the specifications."

Did your work upon these tar-putty lamps show that such a difficulty in fact exists?

A. No, it did not. There is no difficulty whatever in rolling tar-putty and producing a thin, uniform thread, as described in the patent in suit. The lamps made by me have filaments five inches long before carbonization, or about $4\frac{1}{2}$ inches long after carbonization. This is considerably longer than the filament shown in the drawing of the patent in suit. Filaments of this length, and from six to ten thousandths of an inch in diameter can be easily rolled, and I rolled three filaments over 12 inches long, and .007 in diameter, without any difficulty, only four attempts being made in producing three such filaments. These three filaments are the ones in the exhibit, Howell's Tools. The thinner these filaments are made by rolling the harder and denser they get. Filaments which are somewhat soft and sticky when we start rolling them, become hard and lose their stickiness entirely, when they get thinner, so that it is much easier to handle and manipulate a thin tar-putty filaments than it is a thick one.

14 Q. Another difficulty stated by Prof. Thomson is the coiling of such a thread into a helix or spiral—a manipulation which he says is "almost impossible, in fact, without stretching or further deforming the plastic thread." Does this difficulty exist as a fact?

A. No, it does not. I cannot imagine a much easier process than coiling one of these tar-putty filaments upon a mandrel. In doing this I used th: mandrel numbered 3 in the Exhibit Howell's Tools. The tar-putty filament had platinum tips put on it before coiling. In coiling it one of these platinum tips was placed in the little clamp upon this mandrel, the mandrel being held so that the filament hung free in the air. The mandrel was turned, thus winding the filament up upon the mandrel, and forming a spiral. These filaments, when rolled thin, are so hard that they may be supported in this way by one of the platinum tips, without stretching or in any way deforming the filament.

15 Q. Prof. Thomson gives several reasons why the manipulation described in the patent of winding the tar-putty thread between a helix of copper wire, and

carbonizing it while so wound, would in his opinion result in failure. These reasons are given on pp. 1497 and 1498 of the printed record. Please state what was your experience with this manipulation, and state what, if any, of the difficulties stated by Prof. Thomson you found to be present, as a matter of fact?

A. My experience in winding these tar-putty filaments between the coils of a copper helix showed that it was an easy and perfectly practicable method of making tar-putty spirals. If the objections which Prof. Thomson mentioned exist at all, they exist in such a small degree as not to affect the practical working of the operation.

Prof. Thomson sees a difficulty in the softening of the tar composition when it is heated. This tar-putty softens very little, if any, when heated (I refer to these filaments). This fact is shown by the filaments made in the form of a loop, which form part of the Exhibit Howell's Tar-putty Lamps. These filaments, with the platinum tips attached, were hung over a piece of arc-light carbon and heated. Under these conditions the weight of the legs of the loop and the platinum tips was carried by the arch of the loop, which rested upon the arc-light carbon. If this material softened when first heated, the under side of the arch would be flattened. It is not flattened. Consequently I infer the material does not soften with heating. Pieces of carbon Nos. 16, 17 and 18 in Exhibit Howell's Tools are taken from tar-putty loops made in this way and they show no flattening.

The carbon may cement itself to the copper during carbonization, but, if it does, when the copper is eaten away by nitric acid this sticking does not rupture the carbon, nor in any way injure it.

16 Q. Another difficulty stated by Prof. Thomson is the securing of the platinum tips to the tar-putty filament before carbonization, and carbonizing the filament with the tips secured to it. The reasons why this would be unsuccessful are stated by Prof. Thomson on page 1498 of the printed record. Do you agree with Prof. Thomson that lamps made in this way would

not be serviceable or practicable, and are the reasons stated by him well founded in fact?

A. I experienced no difficulty whatever in attaching the platinum wires to the tar-putty filament before carbonization and successfully carbonizing the filament, thus making a perfectly good joint between the platinum and carbon. The first time I tried this it was successful, and during all my experiments I had no trouble whatever with this process. Prof. Thomson's statement that "this composition is practically limber and without rigidity during carbonization" is disproved by my experiments, which show that when first heated the thin tar-putty filaments immediately become hard and rigid, and do not again become soft, and that the filament is capable of supporting the weight of the platinum tips during carbonization without stretching or distorting the filament. Therefore, since the filament itself is capable of supporting the wires, no method of supporting them independently of the coil is necessary.

Adjourned until Wednesday, July 9, 1890, at 10 A. M.

New York, July 9, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

17 Q. Another difficulty stated by Professor Thomson is that of "getting a thorough degree of carbonization throughout the structure and without rupture and displacement of parts." Professor Thomson thinks that a shrinkable mandrel would be necessary to avoid this difficulty. Does this difficulty exist as a matter of fact, and did you find it necessary to employ a shrinkable mandrel in the carbonization of these tar-putty filaments?

A. No. I experienced no difficulty from rupture and displacement of parts during carbonization and did not employ a shrinkable mandrel. The first eighteen lamps were carbonized without any mandrel at all, merely relying upon the powdered plumbago in which they were packed to prevent displacement of parts. The lamps Nos. 19 to 26 were carbonized between the coils of a copper helix which prevented the displacement of parts, and the fact that the carbons came out whole showed that there was no liability to rupture during carbonization.

18 Q. Other difficulties stated by Professor Thomson are those of obtaining coils with evenly spaced turns, the lessening of the durability of the lamp by reason of the spiral form of the burner producing higher temperatures on the interior of the spiral than upon its exterior, and the unequal heating of the spiral burner which he thinks would be materially hotter at middle portions of the coils than near the ends of the coils and which he thinks would make the durability of the lamp most problematical to say the least? Do these difficulties exist as a matter of fact?

A. In lamps made as were lamps Nos. 1 to 18 which were coiled upon a mandrel without any means of obtaining an even spacing of the coils and which were removed from the mandrel before carbonization there is some difficulty in obtaining an even spacing of the coils. In lamps wound between the coils of the copper helix no such difficulty exists, in fact it would be hard to make lamps in this way in which the coils were not evenly spaced. The spiral form of the burner undoubtedly does produce unequal heating, but not sufficiently to impair the durability of the lamp to any great extent. The fact that commercially good spiral lamps can be made having a long life is shown by the life-test made upon six lamps in the Exhibit marked "Howell's Tar-putty Lamps." These six lamps were all spirals and gave a good commercial life.

19 Q. Is the difficulty of getting evenly spaced coils when lamps are made as were your lamps Nos. 1 to 18 so great as to short-circuit a portion of the turns by contacts laterally so as to make a lamp made in this way unserviceable?

A. No. In no lamp made in this way was there a short-circuit between the coils. Lamp No. 6 of Exhibit marked "Howell's Tar Putty Lamps" shows the greatest inequality of spacing of any lamp made by me, but even in this lamp I do not think the inequality sufficient to impair the durability of the lamp to any very great extent. Care in placing these lamps in the powdered plumbago in which they are carbonized will prevent any great inequality in spacing.

20 Q. Another difficulty which Prof. Thomson says is a very serious one, is that the lumps of the tar-putty composition which connect the platinum tips with the filament "would, after the lamp was finished, give out gases gradually and spoil the vacuum." Does this difficulty exist as a matter of fact?

A. The tar-putty connections between the filaments and the platinum tips do contain gases, and if these gases were not removed during exhaustion would cause the difficulty mentioned by Prof. Thomson. But the heating the carbon by the electric current during the exhaustion of the lamps removes the gas from these tar-putty connections and entirely obviates the difficulty mentioned by Prof. Thomson. The six lamps on which the life-test was made showed no depreciation of the vacuum at the end of the 600 hours which they were burned.

21 Q. In answer to question 10 Prof. Thomson gives the various reasons why in his opinion, a lamp like that shown in the drawing of the patent in suit made by processes known to the art at the date of the patent could not be used commercially even if improved lamps had not been devised subsequently. These reasons are, in substance, (1), lack of uniformity in the temperature or incandescence of all lamps of the system; (2), lack of uniformity in color of light emitted from all the lamps; (3), lack of uniformity in the effective radiating surface for lamps of the same candle power; (4), the lowering of the vacuum; (5), the fatal defect of attaching the wires to the burners before carbonization, thus setting the conditions of the lamp and preventing variability or adjustment. Do these difficulties in fact

exist at all, or to an extent to warrant the conclusion reached by Prof. Thomson?

A. Difficulties numbered 1, 2 and 3 do exist in these lamps and in fact they exist in the best lamps made to-day. These difficulties are overcome to-day by a selection of lamps to be burned on any one circuit, and the same method would overcome the difficulty in the tar-putty lamps. Complainant's Exhibit "Howell's Statement No. 1," shows a remarkable uniformity in lamps of the same size, and I think that these difficulties exist in a less degree in tar-putty lamps than in some lamps at present made and used with very great success. Difficulties numbered 4 and 5 do not exist in a degree sufficient to impair the practical durabilty or usefulness of the lamp. Difficulty No. 4 is entirely overcome by heating the carbon during exhaustion with the electric current, a process which is necessary in every lamp made at the present day. Difficulty No. 5 does not exist at all. Setting the conditions of the lamps and preventing variability or adjustment, if it be a difficulty at all, does not affect the commercial usefulness of the lamp, as the testing and sorting necessary for all lamps, whether the conditions are set or not, prevents this setting of the conditions having any effect upon a finished lamp. This defect of setting the conditions of the lamp before carbonization is present in every lamp made by the Edison Company during the first six or seven years of its existence, in the same degree in which it exists in these tar-putty lamps, and it certainly did not prevent these lamps from being practically and commercially successful.

22 Q. In answer to x-Q. 264, Prof. Thomson states that the reference to the length and diameter of the tar-putty filaments and the reference to the thread carbon which the patent says has two thousand ohms resistance and presents a radiating surface no greater than $\frac{3}{16}$ of an inch for certain reasons given by him has but one meaning, and that is "the spiral was to be a closely wound—almost closed spiral." Do you agree with Prof.

Thomson that a tar-putty filament a foot long and $\frac{7}{1000}$ of an inch in diameter or a carbonized thread of 2,000 ohms resistance would have to be made as a closely wound—almost closed spiral?

A. The patent indicates a restriction of the radiating surface by coiling, but the degree of this restriction or the closeness of the coiling I do not think is clearly indicated. A cotton thread carbonized having a resistance of 2,000 ohms and presenting a radiating surface of $\frac{3}{16}$ of an inch would not have to be closely coiled.

Carbonized cotton threads having a resistance of 2,000 ohms and a radiating surface of $\frac{3}{16}$ of an inch made from ordinary commercial sizes of spool cotton can be made without coiling at all. I do not think the patent intended the use of a filament twelve inches long and $\frac{7}{1000}$ of an inch in diameter, and indeed such a lamp would be unlike any lamp ever produced by the Edison Company. I think these dimensions are given to show the possibilities of working the tar-putty, and not as indicating the size of the filament to be used. The drawing of the patent shows an open spiral, and a filament having a length of only about three inches. I do not see anything in the patent to indicate what degree of restriction by coiling was intended.

23 Q. Have you examined the model on file in the Patant Office of the patent in suit?

A. I have.

24 Q. Have you measured the dimensions (length and diameter) of the burner represented by that model, and if so what are they?

Objected to as immaterial.

A. I have examined and measured this model. The filament is, as nearly as I can measure, 15 thousandths of an inch in diameter and $4\frac{1}{2}$ inches long.

25 Q. Assuming that the burner of the model were made of the tar-putty composition described in the patent in suit what would be the resistance, measured cold, of that burner?

Same objection.

A. 86 ohms, providing the measurements I have given above are exactly right.

26 Q. If any of the lamps of the Exhibit "Howell's Tar-putty Lamps" have the dimensions of the burner of the Patent Office model, please state which ones they are?

A. Lamps Nos. 23 and 26 in Exhibit "Howell's Tar-putty Lamps" have very nearly the same dimensions as the Patent Office Model.

27 Q. What would be the resistance measured cold of the burner shown in the drawing of the patent in suit assuming it to be made of the tar-putty composition?

Objected to as immaterial.

A. Taking the dimensions from the straight drawing, Fig. 2, of the drawing of the patent in suit, this filament, if made of tar-putty, would measure about 25 ohms cold.

Adjourned for lunch.

Resumed.

28 Q. Who, if anybody, acted under your direction in making the life and candle-power tests of the tar-putty lamps as to which you have testified?

A. These tests were made in Edison's laboratory in Orange, and were under the personal supervision of Mr. Chas. Deshler, who carried out my instructions regarding the lamps.

29 Q. Who, if anybody, is acquainted with the work you did in the manufacture of the tar-putty lamps about which you have testified?

A. Mr. Francis E. Jackson occupies the desk next to mine at the lamp factory. He witnessed a great many of my experiments in making the tar-putty lamps, and assisted me in many of the operations.

30 Q. Are the carbon filaments of incandescent lamps

inclosed in all-glass vacuum chambers like that described in the patent in suit practically stable or free from disintegration under the conditions under which such lamps are commercially used?

A. The carbon filaments of incandescent lamps are practically stable under the conditions in which they are ordinarily used. There is a very slow wearing away of the carbon filament, and a deposit of carbon molecules upon the inside of the glass globe. This wearing away is hardly rapid enough to be called disintegration, and during the ordinary life of incandescent lamps amounts to very little. Measurements fail to show the diminution in size of a carbon filament which has burned 1000 hours. Such a filament having a rectangular section still retains its sharp corners at the end of that time; and while measurements of resistance indicate a reduction in size of the filament, this is so small that during the ordinary lifetime of an incandescent lamp, it amounts practically to very little. Lamps, as made to-day, may be burned 600 or 1,000 hours, and still be serviceable lamps that give satisfaction to the users.

31 Q. Do your observation and experience show that the breaking of the carbon filaments in these lamps is due to disintegration of the carbon?

A. I do not think the breaking of a carbon filament is ever caused by the action mentioned in my last answer. I have observed a good many lamps which have burned both long and short periods, many of them for several thousand hours; and I do not think any lamps ever break from this cause.

Direct examination closed.

Adjourned until Thursday, July 10, 1890, at eleven A. M.

NEW YORK, July 10, 1890.

Met pursuant to adjournment.

Present—R. N. DYER, for complainant; S. A. DUNCAN, counsel for defendant.

CROSS-EXAMINATION BY S. A. DUNCAN:

31 x-Q. Please explain a little more fully than you have done the method which you adopted for making and treating the lampblack used in your experiments?

A. At the Edison Lamp Factory the lampblack carbon-telephone buttons are made for the Edison carbon telephone. The lampblack I used in making these tar-putty lamps was made for these carbon buttons. It was made before I made these experiments. It was made by allowing a kerosene lamp to smoke its chimney, the soot collected from the inside of the chimney being the lampblack I used. The lampblack was placed in the carbon boxes No 12 and 13 in Exhibit Howell's Tools, packed in a crucible with plumbago, and heated in the same furnace in which the filaments were afterwards carbonized, and to the same degree. The lampblack was in the furnace at least an hour, and probably not very much more than an hour, the object of this process being, in my mind, to drive any moisture out of the lampblack which it may have absorbed.

32 x-Q. In what proportions did you use the lampblack and the tar, when you came to make your composition?

A. In making this mixture I added lampblack to the mixture, little by little, until it was about as thick as thick putty. The proportions I do not know accurately.

33 x-Q. Did you use substantially the same proportions for all of the burners involved in your experiments?

A. Yes; as far as I know, exactly the same.

34 x-Q. What was the method adopted by you for mixing the lamp black and tar?

A. I placed some lamp black on a glass plate and added some of the coal tar to it, mixing them together with a knife, then sprinkling more lamp black on the plate, rolling the previous mixture in it, continuing this process, using only the knife and my fingers in making the mixture.

35 x-Q. How long a time was consumed?

A. About an hour.

36 x-Q. Why did you select coal tar rather than wood tar?

A. The use of coal tar rather than wood tar is clearly indicated in the patent, which says that the lamp black is moistened and kneaded until it assumes the consistency of thick putty. You cannot moisten lamp-black with wood tar, which is itself nearly solid, while you can moisten it with coal tar, which is liquid. Neither could you make a mixture having the consistency of thick putty by mixing lamp black with wood tar, which itself has a consistency thicker than thick putty, while a mixture having such a consistency can readily be made by using coal tar.

I may further add that the patent mentions the plastic lampblack and tar, both for the making of the filament and also the connections with the platinum tips. I do not think such a plastic mixture could be made which would answer the requirement of these uses, if wood tar were used, while coal tar admirably suits the purpose.

37 x-Q. Have you ever tried wood tar for this purpose?

A No. I took some wood tar and tried rolling filaments from it, and it is too stiff to roll filaments from nicely. If we make it still stiffer by adding lamp black, I do not think it could be rolled practically.

38 x-Q. Are you quite correct in indicating that wood tar is necessarily "nearly solid"?

A. At ordinary temperatures, to the best of my knowledge, wood tar is nearly solid.

39 x-Q. Do you know whether the coal tar which you used was in the condition in which it came from the retort, or had it been subjected to some additional process after leaving the retort?

A. My assistant, Mr. Jackson, obtained this coal tar for me from one of the gas works in Newark. I believe it was used in the condition in which it is produced at the gas works. I mean crude coal tar.

40 x-Q. Would the density of a tar and lamp black mixture vary with varying proportions of the ingredients?

A. Probably it would. I did not try varying proportions, and cannot speak from experience.

41 x-Q. Do you know the relative densities of coal tar and lamp black?

A. No.

42 x-Q. Would it be possible, by the process which you adopted in rolling your tar-putty mixture into filaments, to produce two filaments of the same diameter, but of different densities?

A. I do not know by experience. Probably it would.

43 x-Q. Would not the density of the filament depend very largely upon the amount of compression which the material would undergo in being reduced to its ultimate diameter?

A. I think not.

44 x-Q. Is it then your belief that a tar-putty mixture, such as you used, undergoes no compression in the process of being rolled out into thread-like forms?

A. Very little, if any. The dimensions of the piece you start rolling will determine fairly well the size to which it can be rolled, assuming the rolling process to be the one I used.

45 x-Q. Is it your belief that if you were to take two pieces of your tar putty, one the size of a No. 8 bird shot and the other the size of a buck shot, and were to roll each down to a diameter of .007 inches, the densities of the two pieces would remain the same?

A. I have made no experiments of this nature, but I believe their densities would be practically the same.

46 x-Q. What is the relation between the density and the conductivity of these tar-putty filaments which you made?

A. I don't know.

47 x-Q. Will it not be true of a tar-putty carbon filament that its conductivity will increase with an increase of density, and *vice versa?*

A. Probably it will.

48 x-Q. And would it not also be true of these tar-putty carbons that their resistance would vary inversely as their conductivity?

A. It would undoubtedly, as will any material.

49 x-Q. If, then, you had given the total resistances and the sizes as to length and diameter of two tar-putty carbons, could you from such data determine the relative conductivities and the relative densities of those carbons?

A. Yes; probably you could. You certainly could determine their relative conductivities, and get some idea of their relative densities. But unless you know the law governing the rate of variation of density and conductivity, you could not determine the densities accurately. I do not know this law.

50 x-Q. Do you mean that you are ignorant of this law as regards electrical conductors generally, or simply in regard to carbon conductors for electrical lamps?

A. I do not know the law governing the rate of variation of density and conductivity which applies generally to all substances. Nor do I know any such law which applies generally to carbon conductors?

51 Q. Do you know of such a law as applicable to any kind of conductors?

A. I believe that in any metallic conductor the conductivity increases with the density, comparisons being made between different densities in the same substances only, and not generally between different substances.

52 x-Q. Have you any reason to believed that a similiar law does not exist with relation to carbon?

A. Such a law probably does apply to different specimens of carbon of the same composition and nature.

Adjourned for lunch.

Resumed.

53 x-Q. Other things being equal, how does the resistance and how does the conductivity of an electrical conductor vary, relatively to the diameter of such conductor?

A. In round conductors the conductivity varies directly as the square of the diameter, the resistance varying inversely as the square of the diameter.

54 x-Q. Have you in this deposition set forth all the experiments which you have made at any time by way of making or of using tar-putty burners for incandescent lamps?

A. No. Exhibit Howell's Statement No. 2 gives the results of my work, beginning April 2d. Previous to this time, during part of the month of March, I had made experiments in mixing, rolling and carbonizing tar-putty filaments.

55 x-Q. And did you also test in lamps the filaments made during the month of March?

A. No. No filament made in the month of March, with one exception, was ever put into a lamp bulb. This one exception is a loop-filament, which is still in my possession, and which never has been burned, after it came off the pumps. The first finished lamps I made—in fact all finished lamps I made—are included in the Exhibit Howell's Statement No. 1, and with the one exception above noted, every filament made by me which was put into a lamp bulb is included in this statement.

56 x-Q. Did you make any experiments on this subject prior to March?

A. No.

57 x-Q. How extensive were your experiments in the month of March?

A. My first experiments were in mixing and rolling the tar-putty. Rolling these long thin filaments requires a knack which only practice gives, in order to make a filament of uniform diameter. My experiments on different methods of rolling are spread out through a period of probably a week or ten days. Experiments

in carbonizing probably extended over an equal period of time.

58 x-Q. Did you in your first carbonizing experiments make use of the carbonizing frame marked No. 7 in your exhibit of tools?

A. No.

59 x-Q. Did you in your first carbonizing experiments subject the green carbon to a drying process before putting them into the carbonizing furnace?

A. No. My first carbonizing experiments were made without this drying process, my endeavor being to bring up the heat in the furnace gradually; but the burner of the furnace—it being a gas furnace—was so constructed that I could not bring up the heat slowly, and had to substitute the dryer for the first slow heating in the furnace.

60 x-Q. Did you buy this furnace for special use in these experiments?

A. Yes, I did.

61 x-Q. At the time of these experiments were you familiar with the nature of experiments on tar-putty filaments which had been made in certain suits in England, involving one of Mr. Edison's patents?

A. No. I was advised to read over these at the time when I commenced these experiments, but I neglected to do so; I never have read them, nor am I acquainted with their nature.

62 x-Q. Where did you get the idea of using the copper frame marked No. 7 in the Exhibit Howell's Tools?

A. The first lamps I made were made without this tool, I then had this tool made; the idea of using it and its design being entirely original with me. I used it in making several of the lamps, but in the last eight or ten lamps made I did not use it in the carbonization.

63 x-Q. What was the function of the small carbon rod which you introduced into your spirals after the withdrawal of the wooden mandrel upon which the spirals were wound?

A. It was a support, which enabled me to handle the spiral without touching the spiral itself with the tool. In filaments which were put into the dryer before carbonization, this carbon piece supported the spiral while it was in the dryer, the spiral being then removed from the support and packed in the powdered plumbago during carbonization, without any support except the plumbago in which it was packed.

64 x-Q. As I understand you, after you had carbonized these spirals and loops you passed the electric current through them at the time when you were exhausting the bulb of the lamp. Why did you do this?

A. To drive the gases out of the carbon which, if left in, would come out when the lamp was burning and spoil the vacuum. This process is in universal use to-day, and was well known at the date of the patent in suit.

65 x-Q. Do you mean that it was well known as a practical thing in incandescent lighting at the date of the patent in suit?

A. A description of the process had been published to the world as a process to be employed for this purpose; so I assumed that it was well known.

66 x-Q. Where had a description of this process been published?

A. In defendant's Exhibit Edison's French Patent No. 130,910, dated May 28, 1879. Also in the Sawyer-Man U. S. Patents Nos. 210,809 and 211,262, both granted before the date of the patent in suit.

67 x-Q. Did you apply this process of electrical heating of the carbon during the process of exhaustion to all of the lamps embraced in your Exhibit Howell's Statement No. 1?

A. Yes; all of these lamps were heated electrically during the process of exhaustion to a degree of incandescence far above their normal degree, and maintained so for a considerable length of time. They burned when on the pumps fully three-quarters of an hour, and for fifteen or twenty minutes at least were burned higher than their normal rate of burning. All were treated alike.

68 x-Q. How much above the normal temperature did you carry these burners during this electrical heating?

A. I made no measurements to determine this, but I believe they were burned at four or five times the candle power at which they were tested.

69 x-Q. Why did you make use of this extraordinarily high temperature?

A. This is not extraordinarily high. Regular lamps of our present manufacture are run much higher than this. As no limit to the process is stated in the publications I have mentioned, and a very high degree of incandescence is mentioned in them, I felt at liberty to use my own judgment in the matter.

70 x-Q. Why did you not carry the temperature up to that degree which is adopted by the Edison Company in their commercial manufacture?

A. Because I did not wish to run any risk of breaking the lamps. I did not believe these tar-putty lamps would stand as high working as the present Edison lamps; so I ran them at a safe temperature which I considered high enough for all practical purposes.

71 x-Q. Mr. Edison, I believe, has taken out a patent, has he not, for a process of heating carbons during exhaustion of the lamp-bulb, in which the essential feature consists in carrying the temperature of the carbon up to a point higher than that at which the lamp is to be run in actual service?

A. I don't know.

72 x-Q. Do you know when first the Edison Company practiced the method of electrical heating of incandescent lamp carbons which consists in raising the temperature of the carbon during the exhaustion of the globe to a point in excess of that which the lamp is to be run in service?

A. No; I do not. It certainly was before my connection with the Edison Company, and before I had any knowledge of their processes of manufacture.

73 x-Q. What is the specific resistance of the carbon composing the burners of the lamps named in Howell's Statement No. 1?

A. The resistance cold of one cubic thousandth of an inch of tar-putty carbon, as made by me is 3.3945 ohms, the same hot being 2.0299 ohms.

74 x-Q. On this basis what would be the absolute resistance of a cubic centimetre of the carbon composing the burners of these lamps, measured in microhms? And how can this result be obtained from the data which you have already given?

A. Tar-putty carbons, 8617 microhms per cubic centimetre. To get this figure I used the average resistance, cold, of the seventeen lamps in Exhibit Howell's Statement No. 1, which were made from filaments, .010 inch in diameter, their average resistance being 233.3 ohms. The size of these filaments, after carbonization is 4.37 in. long, and .009 in. diameter. From these figures the resistance of .001 cubic in. as stated in 73 x-A. was found by following the formula: Resistance of one cubic thousandth $= \frac{233.3 \times 63.6}{4370}$; 63.6 being the area of a section of the filament in square thousandths of an inch, and 4370 being the length of the filament in thousandths of an inch. This equation gives me 3.3945 ohms as the resistance of one cubic thousandth of an inch. From this figure I determined the resistance of one cubic centimetre by the following equation $\frac{3.3945 \times 393.9}{393.9^{(2)}} =$ .008617 ohms. This expressed in microhms is 8617.

75 x-Q. Does this process of electrical heating during exhaustion which you practiced with the lamps of Howell's Statement No. 1, and which the Edison Company practices in the manufacture of its bamboo lamps, produce any change in the resistance of the carbon?

A. Yes.

76 x-Q. How much?

A. That depends upon the temperature at which the filament is carbonized. The higher the temperature of the furnace is, in which the carbonization was done, the less the change in resistance by electrical heating. The tar-putty lamps which I made were carbonized at

a very low temperature, and their resistance was reduced considerably by the electrical heating during exhaustion. Edison lamps as manufactured regularly are carbonized at a very high temperature, and change very little in resistance during the electrical heating during exhaustion.

77 x-Q. Does the amount of this change in resistance depend also upon the temperature adopted during the electrical heating?

A. Yes, it does. The higher the lamp is heated during exhaustion, the greater change will be made in resistance.

78 x-Q. You made an affidavit, I believe, in the suit in Canada between the Royal Electric Co., and the Edison Electric Light Co.?

A. Yes.

79 x-Q. In that affidavit which was verified by you November 10, 1888, you testified, did you not, that the electrical heating of the carbon burners of the Edison lamps during the process of exhaustion, as such process was then carried on in the Edison factory, reduced the electrical resistance of carbons about 20% on the average?

A. Yes.

80 x-Q. Does that figure fairly represent the reduction in resistance caused by this process of the electrical heating of the burner during exhaustion, as such process was carried on by the Edison Company in November, 1888?

A. Yes, I believe it does.

Adjourned until Friday, July 11, 1890, at 11 A. M.

NEW YORK, July 11, 1890.

Met pursuant to adjournment.

Present—R. N. DYER, and G. P. LOWREY, of counsel for complainant; S. A. DUNCAN, of counsel for defendant.

CROSS-EXAMINATION OF THE WITNESS, JOHN W. HOWELL CONTINUED:

81 x-Q. What reduction in resistance took place by the electrical heating during the process of exhausting the globe to which you subjected the tar putty carbons of the lamps named in Exhibit Howell's Statement No. 1?

A. I made measurements on some of these lamps before and after exhaustion, and found their resistance after exhaustion to be only from one-twentieth to one-fortieth of the resistance before exhaustion. This figure is not accurate, because the connection between the platinum tips and the leading in wires also reduce in resistance during the heating on the pumps. However, there undoubtedly was a very great reduction of resistance.

82 x-Q. Did you observe whether this great reduction in the resistance was accompanied with any change in dimensions, especially any change in cross-section?

A. No, I did not; I did not measure any carbon after the exhausting process; I did notice, however, that during the exhaustion and heating there was absolutely no distortion of the carbon filament. From this I would infer that there was no change in the dimensions of the filament. The very finest spirals preserved the uniform spacing of the coils, although they were heated very high during the exhaustion

83 x-Q. Did you use as high a heat for your tar-putty burners in the carbonizing furnace as the Edison Company are in the habit of using with their bamboo burners?

A. No. The crucible in which I carbonized the tar putty filaments was only raised to a dull red heat,

which was below the melting point of copper. The regular carbonizing as done by the Edison Company is carried to a temperature of such a dazzling whiteness, that it hurts the naked eye to look into the furnace through a small opening.

84 x-Q. How did the temperature used by you in the carbonizing furnace compare with that used by the Edison Company in 1888?

A. It was very much lower.

85 x-Q. Why did you employ this excessively low heat?

A. Part of the filaments were carbonized between the coils of a copper helix, as described in the specification of the patent in suit. This must necessarily be done at a temperature below the melting point of copper, or the copper, being melted, will break the filament. To carry out the instructions of the specification in this respect, it is necessary to keep the temperature of carbonization below the melting point of copper.

86 x-Q. With those carbons where the copper spiral was not used, why did you not employ a higher heat?

A. Some of these were carbonized in the copper saddle, No. 7 of Exhibit Howell's Tools. This made it necessary to limit the temperature as before stated, and knowing that some of the carbons, I mean the ones to be wound between the coils of the copper helix, would have to be carbonized at this low temperature, I used about this temperature in all my carbonizations.

87 x-Q. How long were these tar putty carbons kept in the furnace?

A. I found that the copper would be fused, as the furnace was usually run, in an hour and a quarter, so I ran the furnace one hour during most of my carbonizations.

88 x-Q. For about what time are the Edison bamboo fibres kept in the carbonizing furnace?

A. I do not know. This process is not carried on in the factory in which I am employed, and I have never visited the place where it is carried on. And I really know nothing about it.

89 x-Q. Have you not known about it at some time during your employment by the Edison Company?

A. Yes, I have had a general knowledge of it, but never an accurate knowledge. I believe the process occupies several hours.

90 x-Q. What was the resistance of your tar-putty filaments before they were put into the carbonizing furnace?

A. I believe the filaments before carbonization are insulators, and not conductors.

91 x-Q. Have you ever tested them in this regard?

A. No, but the nature of the materials indicates that they are insulators.

92 x-Q. Is not coal tar a conductor of electricity?

A. I think not.

93 x-Q. Do you know?

A. I have never tried it, but I should be very greatly surprised to find that it was.

94 x-Q. Have you ever seen in any electrical authority a statement that it is not a conductor?

A. No.

95 x-Q. Carbon is a conductor of electricity, is it not?

A. Yes.

96 x-Q. The fact then, as I understand it, is that you never measured the resistance of your tar-putty filaments in their green condition, that is before their introduction into the carbonizing furnace?

A. No. I never have.

97 x-Q. How long a time do you find requisite for rolling out a filament like specimens 19, 20 and 21 in your Exhibit Howell's Tools, after the mixture has been made?

A. About an hour. Probably less than this; certainly not more.

98 x-Q. Approximately what is the radiating surface of one of these filaments 19, 20 and 21?

A. About 0.286 sq. in.

98 x-Q. And what approximately is the resistance of one of these filaments after carbonization?

A. About 1,200 ohms, assuming the length to be thirteen inches.

100 x-Q. You say, in answer to 22 Q. that carbonized cotton threads can be made from ordinary commercial sizes of spool cotton, having a resistance of 2,000 ohms, and a radiating surface of $\frac{3}{16}$-inch. Do you know this by actual test?

A. Yes, but I did not make the test myself. Tests showing this fact were made by my assistant, Mr. Jackson, who will testify concerning this matter in this case.

101 x-Q. How far, in your judgment, is the radiating surface of the spirally coiled burners of your Exhibit lamps diminished by the coiling?

A. I have made no measurements or observations to show the amount of this diminution. It is greater in some lamps than in others. The first eighteen of these lamps were coiled to an extent about the same as is exhibited in the drawing Figs. 1 and 3, in the patent drawing. The other spiral lamps are coiled more closely than this, about in the same degree as the Patent Office model of the patent in suit, lamp 23 and 26 being as nearly as I could make them exactly the size of the Patent Office model referred to.

102 x-Q. Did you measure the resistence of the burner in the Patent Office model?

A. I tried to, but found it was a blackened thread, and not a carbon, being made simply as a model to show the dimensions and form of a carbon filament.

> Latter part of the answer beginning with the words "being made" objected to as not called for by the question, and as only a hypothesis on the part of the witness.

103 x-Q. You say in answer to 25 Q. that if the burner of the Patent Office model were made of the tar-putty composition described in the patent in suit, its resistance, measured cold, would be 86 ohms. Should not this statement be qualified by the further hypothesis that the resistance of the tar-putty composition of the patent in suit is the same as that of the tar-putty filaments of the lamps which you have made, after

their resistance has been reduced by electrical heating to from one-twentieth to one-fortieth of the resistance which the same carbons have on coming out of the carbonizing furnace?

A. Yes. I measured the dimensions of the filament in the Patent Office model, and from these measurements and the specific resistance of the tar putty after heating during exhaustion, I obtained the resistance as given in 25 A.

104 x-Q. And would the same qualification attach to your answer to Q. 27 in which you undertake to state the resistance cold of a tar putty burner having the dimensions of the drawing in suit?

A. Yes.

105 x-Q. Please explain briefly how you measured the drawing of the patent in suit in reaching the determination given in your answer to Q. 27?

A. I measured the length between the enlarged ends, and measured the diameter between the inside edge of the heavy shade line forming the right boundary of the filament, to the outside edge of the thin line forming the left boundary, these measurements being taken from Fig. 2 of the patent drawing.

106 x-Q. Do you find anything in the patent which indicates that all the figures of the drawing are made to a definite scale?

A. No.

107 x-Q. In all of the tar-putty carbon lamps which you made, the burners were joined to the platinum tips or wires by the use of the tar-putty cement, and before carbonization; were they?

A. Yes.

108 x-Q. By what manipulation did you apply this cement?

A. I cut off a small, thin piece of tar-putty, and squeezed it around the platinum tip and end of the filament with my fingers.

CROSS-EXAMINATION CLOSED.

RE-DIRECT EXAMINATION BY MR. DYER:

109 Re-d. Q. You have stated how long it took you to roll out the exceedingly fine and long tar-putty filaments Nos. 19, 20 and 21 in your Exhibit Tools; state how long, if you know, it takes to roll out tar-putty filaments of the dimensions used in the lamps which you have produced?

A. I timed myself while making three of the lamps, having filaments .010 inch in diameter and five inches long. I rolled these filaments, attached the platinum tips, coiled them on the mandrel, and placed them upon their supports, ready for carbonization, all this occupying twenty-five minutes for each of these three lamps.

110 Re-d. Q. What is the specific resistance (stated as the absolute resistance per cubic centimetre, in microhms) of the bamboo carbon lamps at present made by the Edison Lamp Company?

A. 5788 microhms per cubic centimetre.

111 Re-d. Q. If incandescent lamps were made without heating the carbon filaments during exhaustion, what would be the effect upon the resistance of such filaments of the electric current used to light them up or burn them in use?

A. The electric current used in burning such lamps would effect a reduction in the resistance of the carbon filaments, depending in amount upon the temperature of carbonization which had been employed in making the lamps.

112 Re-d. Q. How would the reduction compare with the reduction in resistance produced by heating upon the pumps?

A. Assuming a heating upon the pumps such as is employed by the Edison Company, it would not be materially less. I mean that the reduction in resistance caused by the current used in burning such a lamp would reduce the resistance of a carbon filament very nearly as much as would the high heating during exhaustion used by the Edison Company. Especially would this be so if the filament had been carbonized at a low temperature.

113 re-d. Q. With respect to the dryer which you used in your work on tar-putty lamps, did you use this with all the filaments; and is such a dryer a usual or unusual laboratory contrivance?

A. Some of the filaments were made without drying in this dryer. A drying oven is a common piece of apparatus, and is found in every laboratory, being used for drying or driving off the volatile ingredients of any substances being experimented upon.

114 re-d. Q. Have you brought with you, since yesterday's session, samples of the coal tar and calcined lampblack which you employed in making the tar-putty mixture?

A. Yes. I hereby produce them, in bottles properly labeled.

Counsel for complainant offers in evidence the bottles and contents produced by the witness. The same are marked respectively Complainants' Exhibit Sample of Coal-tar, and Complainants' Exhibit Sample of Lampblack.

Re-direct examination closed.

Re-cross Examination by Mr. Duncan:

115 re-x-Q. Do you intend your answer to 112 re-d. Q to apply to tar-putty carbons?

A. Yes.

116 re-x-Q. What experiments have you ever made with the tar-putty carbons that justify such a statement with respect to them?

A. None; but I have made experiments with other carbon; and as the effects produced in both carbons are of the same nature, I assume that what I have previously said applies to tar-putty carbons. In all cases the reduction in resistance is caused by heating the carbon to a very high temperature; and I do not think the effect would be any less, if the lamp were not upon a vacuum pump, than it would be upon such a pump. The resistance of a tar-putty carbon burned in a lamp made without heating during exhaustion would, I believe, be reduced to a much lower point than would the resistance of such a carbon by high heating during exhaustion; because such a tar-putty filament, having been carbonized at a low temperature, still contains some hydro-carbons that have not been decomposed during carbonization. These hydro-carbons would be decomposed by the high temperature of the carbon when it is burned, and the pressure of the gas so produced would, I believe, reduce the resistance of the filament. This view is supported by the fact that, during the burning of th: six lamps of Exhibit Howell's tar-putty lamps, which were tested for life, a reduction of their resistance took place, which, I believe, was cause by the decomposition of the tar-putty used in connecting the platinum tips to the filament which tar-putty was not heated to a high degree during exhaustion, and would act the same in a finished lamp as would the carbon previously referred to as having not been heated during exhaustion. This decomposition of hydro-carbons driven by the heat of the lamp from connection between the platinum and the carbon filament and the reduction in resistance during the burning of a lamp caused by gas so produced, I have observed in lamps having connections between platinum and carbon made by the deposition of carbon from a hydro-carbon liquid, such action being very slow and extending over a long period of time during which the lamp was burned.

117 Re-x-Q. In the lamps which you made, was not the plastic carbon which was used at the joint between the burner and the platinum wire, as well as the burner itself, subjected while on the pumps to an electric current of much greater intensity, and therefore to a much higher heat, than that employed after the lamps were sealed up?

A. Yes.

118 Re-x-Q. And is it your idea, then, that if the electrical heating on the pumps had not been used the comparatively low heat employed in testing the finished lamps would have caused a greater reduction in resistance than was produced by the very high current to

which in fact you subjected the lamps while on the pumps?

A. Yes, I believe so; the reduction, however, would be due to different causes. A very great reduction would be made by simply heating the filament while burning; and a further reduction would be made by the action I have previously mentioned. While the first of these two causes would probably not produce as great a reduction as would the high-heating during exhaustion, both actions together would, I believe, produce a much greater reduction than was produced by high heating during exhaustion.

119 Re-x-Q. Then I assume that you would give it as your opinion that if you had not heated these lamps electrically while on the pumps, the carbons on the finished lamps, when you came to put the lamps to use with an ordinary service current, would have fallen in resistance gradually to considerably less than one-twentieth to one-fortieth of their resistance when you began burning them?

A. Yes. When first used a very large reduction would immediately occur, which would be followed by a slow reduction. The lamps which were burned on the life-test showed a gradual reduction of resistance during the entire 600 hours in which they were burned.

120 Re-x-Q. The illuminating power would be reduced much more than the resistance, would it not?

A. On the contrary, the illuminating power would increase as the resistance decreased, other things being equal.

121 Re-x-Q. Referring to your answer to 87 x-Q., will you please explain why, if you could keep one of your tar-putty burners in the carbonizing furnace for an hour without melting down the copper with which it was associated, you might not have kept it there for ten or twenty hours if you had so desired?

A. The filaments in their carbon boxes were placed in the centre of a graphite crucible, which was placed inside the furnace. In this position they were so well protected from the heat, and the mass of material forming the furnace itself was so great, and being made still greater by several firebricks which supported the crucible in the furnace, that, starting with the whole thing cold, it took some time to raise the temperature of the mass; and with a given gas flame to heat the furnace, it would take considerably more than an hour for the crucible and its contents to reach their maximum temperature.

122 Re-x-Q. The gas flame was beneath these firebricks on which the crucible rested?

A. Yes.

123 Re-x-Q. And about how large and thick was the crucible?

A. About 8 inches high, about 5½ inches in diameter at the top and about 3 inches at the bottom. And the walls were about ¾ inches thick.

124 Re-x-Q. And was the box which contained the carbons to be treated placed in this open crucible. If not, how otherwise?

A. The box containing the filaments was packed in plumbago in the centre of this crucible, the entire crucible being filled with plumbago, the firebrick being placed on top of it.

125 Re-x-Q. Do you know the melting point of copper?

A. No; but it can readily be obtained from many books containing such data.

RE-CROSS-EXAMINATION CLOSED.

JOHN H. HOWELL.

Adjourned for lunch.

FRANCIS E. JACKSON, a witness produced on behalf of the complainant, being duly sworn, testifies in answer to interrogatories by MR. DYER:

1 Q. What is your name, age, residence and occupation?

A. Francis E. Jackson; aged, twenty-five years; residence, East Orange, N. J.; occupation, electrician in the employ of the Edison Lamp Company.

2 Q. How long have you been employed by the Edison Lamp Company?

A. Not quite four years.

3 Q. I show you a box of incandescent electric lamps, marked Complainants' Exhibit Howell's Tar-putty Lamps. Have you seen these lamps before; if so, under what circumstances?

A. Yes; I have seen those lamps before. I saw them made, most of them, at least, by Mr. John W. Howell, and I assisted in the making of them.

4 Q. I call your attention to Complainants' Exhibit Howell's Tools. Have you seen these tools before; if so, under what circumstances?

A. I have seen them, and recognize them as tools used by Mr. Howell in making the lamps.

5 Q. I read to you 5 Q. and answer of Mr. Howell's deposition in this case, in which he describes the various steps of manufacture followed by him in the production of these tar-putty lamps. Is this statement of Mr. Howell a correct one?

A. The processes, as far as I observed, were exactly as described by Mr. Howell.

6 Q. Mr. Howell has stated that you procured the coal-tar for him. Is that so?

A. It is. I procured the coal-tar at a gas-works in Newark.

7 Q. What was the condition of the coal-tar when you received it, and was it used by Mr. Howell in that condition or otherwise?

A. I saw the tar pumped from the receiver in which it is kept in its crude condition at the gas-works. The tar was used in making the putty in exactly the same condition in which it came from the gas-works.

8 Q. Have you yourself made lamps of other materials than tar-putty described in the patent, and having the filaments made in a spiral form, and secured by the tar-putty composition to platinum tips before carbonization?

A. Yes, I have made lamps of cotton and linen thread, in that way. Some of these lamps were made of thread rubbed with the tar-putty. I have these lamps here in this box, together with the spools of thread of which the lamps were made. I have also with me a statement showing the nature of the filaments before carbonization, and also showing the resistances of the filaments in the lamps, measured cold.

> Complainant's counsel offers in evidence the box of lamps produced by the witness, and the same is marked Complainants' Exhibit Jackson's Thread Lamps.
>
> Complainants' counsel also offers in evidence the statement referred to by the witness, and the same is marked Complainants' Exhibit Jackson's Statement No. 1.

9 Q. Have you made any tests of these thread lamps; if so, please state what they are?

A. I have made such tests, and have with me a table showing the candle power, voltage, amperes, resistance hot and the watts per candle at the candle power at which they were tested. The numbers of the lamps are also indicated, the same numbers being marked on the lamps and also given in my Statement No. 1.

> Complainants' Counsel offers in evidence the statement just produced by the witness, and the same is marked Complainants' Exhibit Jackson's Statement, No. 2.

10 Q. I call your attention to the statement contained in the patent in suit "That if the thread be coiled as a spiral and carbonized * * * as much as 2000 ohms resistance may be obtained, without presenting a radiating surface geeater than $\frac{3}{16}$ of an inch." Does this statement indicate that the spiral is to be closely coiled, so as to produce a very considerable restriction of the radiating surface?

A. It is not necessary to restrict or cut off the radiating surface, in order to obtain a filament as described. The lamp numbered 15 has a resistance of 2,240 ohms, and the radiating surface, even if the filament was not coiled at all, would be less than $\frac{3}{16}$ of an inch. Also the lamp numbered 14 has a resistance of 1,670 ohms. I calculate that if this filament were long enough to give a radiating surface of $\frac{3}{16}$ of an inch, when the filament was not coiled, the resistance would be considerably greater than 2,000 ohms.

11 Q. Have you, at the request of Complainants' Counsel, mounted in a case the incandescent lamps at present manufactured by the Edison Lamp Co., as shown by the list in evidence in this case marked Defendants' Exhibit Complainants' List of Edison Lamps?

A. I have selected lamps such as are at present made by the Edison Lamp Co., and have had them mounted in a case. The lamps were selected so that the voltages would correspond with those indicated on the list referred to. I have pasted labels on these lamps so that they can be identified.

Complainants' Counsel offers in evidence the case of regular Edison lamps produced by the witness, and the same is marked Complainants' Exhibit Sample-Case of Edison Lamps.

Direct examination closed.

Adjourned until Saturday July 12, 1890, at 10 A.M.

New York, July 12, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

Cross-examination of the witness, Francis E. Jackson, by General Duncan:

12 x-Q. Are you an assistant of Mr. Howell?

A. I am not exactly an assistant of Mr. Howell. I was directed by Mr. Upton to assist Mr. Howell in this work.

13 x-Q. How long have been an "electrician"?

A. I have been in the employ of the Edison Lamp Co. as electrician for nearly four years; that was my first position of that kind. I graduated from the Stevens Institute shortly before my connection with the Lamp Co., and took the course in electricity which was provided by the Stevens Institute.

14 x-Q. Do you hold a diploma as an electrical engineer?

A. I hold a diploma as a mechanical engineer, not as an electrical engineer. The Stevens Institute gives no diplomas to electrical engineers, but mechanical engineering and electrical engineering are so closely connected now that the course in mechanical engineering will not be complete without including the study of electricity also. The Stevens Institute provides a course of study of electricity in its course of mechanical engineering.

15 x-Q. Your practical acquaintance with the manufacture of incandescent lamps, such as you have, has been obtained, then, since your employment by the Edison Co.?

A. I knew in a general way the manner in which incandescent lamps were made before my connection with the Edison Company, but I had never made such lamps or seen them made before that time.

16 x-Q. In your course at the Stevens Institute did your professors explain Ohm's law to you?

A. They did.

17 x-Q. So that you had a fair understanding of it?

A. I had.

19 x-Q. Were any of the lamps embraced in Jackson's statement No. 1, subjected to a life test?

A. None of the lamps were so tested.

20 x-Q. How long have any of these lamps been run?

A. Roughly, I should say that none of them have been run more than half an hour.

21 x-Q. Were the carbons of all these lamps subjected to electrical heating on the pumps?

A. All of the lamps were heated on the pumps electrically.

22 x-Q. How did the degree of heat employed for that purpose compare with the heat at which you tested the lamps in procuring the data given in Jackson's statement No. 2?

A. They were all heated on the pumps to a higher temperature than when they were tested. I could not state the temperature in figures, and do not remember ever having heard figures mentioned for the temperature of such lamps when being exhausted.

23 x-Q. The temperature however used at that time was very much higher than the temperature used in the subsequent tests, was it not?

A. The temperature used on the pump was much higher than that used during the tests.

24 x-Q. How long a time was consumed in this electrical heating on the pumps?

A. I did not note the time, but would say about one-half an hour.

25 x-Q. How long were the thread spirals kept in the furnace before they were put into the lamp bulbs on the pumps?

A. There was no fixed time at all of carbonization, but the average time was about three hours.

26 x-Q. How did the temperature of the furnace compare with the temperature used on the pump?

A. The temperature of the furnace was lower than the temperature of the filaments of the lamps, while being exhausted.

27 x-Q. Approximately how much lower?

A. I have no figures to give for the difference in the degrees of temperature, but in the furnace the filaments were heated only to a yellow heat. The filaments could not be seen while in the furnace, but the crucibles were heated to a yellow heat and I assume that at the end of the three hours burning the same temperature had penetrated to the centre of the crucible?

28 x-Q. Were your thread spirals packed in plumbago in small carbon boxes and these boxes in turn packed in a larger mass of plumbago within a large crucible in the manner described by Mr. Howell in his account of his work in carbonizing tar putty filaments, and did you use the same furnace that he used?

A. The thread filaments were packed and carbonized in the same general way as those made by Mr. Howell. The only difference being that no special means of support for the thread filaments were adopted, they being simply laid in the plumbago in a small carbon box.

The carbon box was packed in the larger crucible as described by Mr. Howell. The thread filaments were left in the furnace for a longer time than the tar-putty filaments. The crucible and furnace used were those used by Mr. Howell in carbonizing his tar-putty filaments.

29 x-Q. Then, as I understand, you placed the crucible and its contents while cold in the furnace, then applied the heat and kept the crucible in the furnace until you supposed that the yellow heat, which was first developed on the outside of the crucible, had penetrated to the thread spirals which you were treating, and that you removed the crucible when you supposed this heat had been secured. Was such the fact?

A. The filaments were left in the furnace until I thought they had been exposed to the greatest heat attainable at that time for a sufficient length of time to carbonize them. I believe that before the filaments were taken from the furnace the centre of the crucible was as hot as the outside, and that the centre of the crucible had been at that maximum temperature for some time. When I thought the carbonization was complete the gas was shut off the furnace and the furnace and crucible allowed to cool.

30 x-Q. How long do you think the thread spirals remained exposed to this maximum temperature before the gas was shut off, and what are your grounds for naming any particular time?

A. Generally the heat was not all turned on in the furnace at once. The full flow of gas was not turned on until after the furnace had been warmed by the smaller flame. I would suppose that the filaments were exposed to the highest heat for one half an hour to an hour, but I have no proof that such was the case.

31 x-Q. Then so far as you know the filaments may have been exposed to the higher temperature for two hours ?

A. I think they could not have been exposed to the highest temperature for so long a time because the outside of the crucible was itself only exposed to the highest temperature for about two hours.

32 x-Q. That is, it took one hour possibly to bring the outside of the crucible, through which the heat had to travel to the interior, to a yellow heat ?

A. In a former answer I stated that generally the full flow of gas was not turned on the furnace at first. The outside of the crucible was not raised to its highest temperature in less than an hour, partly because the full flow of gas had not been turned on at the beginning and partly because it took time for the outside of the crucible to attain its maximum temperature when the full flow of gas had been turned on.

33 x-Q. How long a time was required for this after the full flow of gas was turned on ?

A. I cannot state definitely, but would judge about one half an hour.

34 x-Q. Have you any means of knowing that the thread spirals, which were imbedded in the centre of the plumbago in the crucible, were in fact exposed to the highest temperature for more that fifteen minutes ?

A. I have no absolute knowledge that they were exposed to the highest temperature for more than fifteen minutes, but I believe that they were. At any rate it was not my desire to heat them to any particular temperature or for any length of time. I found by experiment that they were carbonized satisfactorily when heated in the way described.

35x -Q. When you say they were "carbonized satisfactorily," you do not mean, I suppose, that they were in condition to be put into lamps and sealed up for commercial use without being subjected to a supplemental high heating, as by the use of the electric current during the process of exhausting the lamp bulbs ?

A. I did not exhaust any lamps without heating the filament by use of the electric current, and therefore cannot say just what the result would have been if they had not been so heated.

36 x-Q. Why didn't you put some of the thread spirals into lamp bulbs and exhaust and seal off the bulbs, without electrically heating the spirals on the pumps ?

A. It did not occur to me to do so. All our lamps are heated in this way and I naturally heated these also.

37 x-Q. Did you test the resistance of any of these spirals after they came from the furnace and before they were put in the lamp bulbs ?

A. I do not remember testing any of these filaments in this way, but I may have done so.

If they were tested I have not kept the figures showing the results of the tests.

38 x-Q. Did you aid Mr. Howell in testing the resistances of his tar-putty lamps ?

A. I did test some of the tar-putty lamps before exhaustion, and also after exhaustion.

39 x-Q. In those lamps you found a very great change in resistance produced by the electrical heating on the pumps, did you not ?

A. I do not remember how much change there was.

40 x-Q. Was the yellow heat which you say was attained by the crucible in you own experiments, and which you assume was attained for a greater or shorter period of time by the thread spirals enclosed within the crucible, greater or less than the heat at which the ordinary incandescent lamp is intended to be run in actual use ?

A. Incandescent lamp filaments in ordinary use are heated to a higher temperature than was attained in the furnace during the carbonization of the cotton thread.

41 x-Q. Then, of course, the heat to which you subjected these thread spirals while on the pumps was very

much higher than the heat to which they were subjected in the furnace?

A. The temperature to which the cotton thread filaments were subjected on the pumps was very much higher than the temperature to which they were subjected in the furnace.

42 x-Q. Is this also true in regard to the tar-putty filaments that were made by Mr. Howell and put into his lamps?

A. The tar-putty filaments were heated to a much higher temperature while on the pumps than was attained in the carbonizing furnace.

43 x-Q. When the tar-putty filaments were being carbonized, what was the heat to which the crucible was brought?

A. In carbonizing the tar putty filaments so great a heat was not used as in carbonizing the cotton thread filaments. Without knowing just what the temperature of the furnace was in carbonizing the tar-putty filaments, I would judge that the crucible was heated to a dull red heat during the carbonization.

44 x-Q. And in the tar-putty experiments was the crucible brought up to this dull red heat by first turning on a small supply of gas and then letting on the full flow, as in the case of your thread spiral experiments?

A. My recollection is that the full flow of gas was not turned on in the carbonization of the tar-putty filaments.

45 x-Q. About how long did it take to bring the crucible to its dull red heat in the tar-putty filaments?

A. I cannot say how long it took, not having observed it.

46 x-Q. To what extent could the flow of gas in the furnace be regulated?

A. The gas could be turned on full when the flame filled the furnace, or it could be shut off so that the flame filled a small part of the furnace.

FRANCIS E. JACKSON.

CHARLES DESHLER, a witness produced on behalf of the complainant, being duly sworn, testifies as follows, in answer to questions by Mr. Dyer:

1 Q. What is your name, age, residence and occupation?

A. Charles Deshler; twenty-seven years of age; New Brunswick, N. J.

2 Q. Have you lately tested for Mr. John W. Howell some tar-putty spiral lamps and, if so, what was the character of the test and what the results?

A. I have tested for Mr. John W. Howell some spiral lamps. I can't say that they are tar-putty, having not received that information. I tested these lamps for life, candle power and efficiency. I tested seven lamps. One No. 5 lamp I found to be a poor vacuum lamp. The remining six I took down at the end of 600¾ hours. I have tabulated the results of life, per cent. candle power and average amperage of these lamps.

> Complainant's counsel offers in evidence the tabulated statement produced by the witness and the same is marked Complainant's Exhibit Deshler's Test of Howell's lamps.

3 Q. I call your attention to Complainant's Exhibit Howell's Tar-putty Lamps and to lamps Nos. 2, 3, 5, 9, 13, 14 and 15. Do you recognize these lamps as the ones you tested?

A. I recognize those as the lamps I tested. They still have my order mark 4454 upon them.

4 Q. What is your occupation?

A. I have charge of the lamp-testing department at the Edison laboratory.

CROSS-EXAMINATION BY GENERAL DUNCAN:

5 x-Q. Why do you say the lamp No. 5 was "a poor vacuum lamp"?

A. On account of the discoloration of the filament, the fact of its heating up intensely and its short life.

6 x-Q. How does the discoloration prove that the vacuum was poor?

A. When the carbon oxidizes it takes a brownish yellow.

C. Deshler.

Adjourned to July 15 (Tuesday), at 11 A. M.

New York, July 15, 1890.

Met pursuant to adjournment.

Present—G. P. Lowrey and R. N. Dyer, of counsel for complainant; S. A. Duncan, of counsel for defendant.

Cyrus F. Brackett, a witness produced on behalf of defendant, having been duly sworn, testifies in answer to questions by Mr. Dyer.

1 Q. Please state your name, age and residence.

A. My name is Cyrus F. Bracket; fifty-six years of age; I reside at Princeton, New Jersey.

2 Q. You are Professor of Physics at Princeton College, have devoted many years to the investigation and exposition of scientific matters—especially electrical matters—and have been frequently called upon to testify as an expert in patent cases?

A. Yes.

3 Q. Have you given any especial attention to the study of electric lighting, and what facilities and opportunities have you had for investigating that subject?

A. I have for many years given especial attention to the study of electric lighting, commencing and carrying on my investigations before the subject had been developed in any practical commercial way. In the year 1863 I was put in charge of the department of chemistry and physics in Bowdoin College, and almost immediately thereupon constructed a very powerful galvanic battery, with which I was enabled to produce many of the results which can now only be produced, in a more economical way, by means of the dynamo-machine. I constructed and operated a very powerful arc lamp and subsequently imported and used an arc-lamp supplied by John Browning, and in the course of my studies became fully aware of the advantages to be derived from a successful and economical production of the electric light. In the year 1873 I became Professor of Physics in the College of New Jersey, where it became my duty to give instructions in various branches of physics, including electricity, electric lighting, etc. In the lectures which I have given to my students I have constantly made use of the various appliances which exhibit the progress and the present state of the art of electric lighting. I have under my control a very large and expensive collection of apparatus suited to the exhibition of the principles involved in the art of electrical illumination, and showing the various methods of their installation in practice.

4 Q. Are you acquainted with the construction and operation of Geissler tubes, and, if so, how extensive has been your familiarity with that apparatus?

A. I am acquainted with their construction and operation, indeed, I have frequently constructed them myself, and applied them for various purposes of research. While at Bowdoin College I had a collection of these tubes in my charge; and I have at Princeton a numerous and valuable collection of Geissler tubes suited to various uses, such as spectroscopic research, exhibition of mechanical effects, thermal effects and many which are for mere display of curious results.

5 Q. Please explain the construction, operation and uses of Geissler tubes?

A. The Geissler tube is constructed chiefly of glass. The form and size of the tube will depend upon the use to which it is to be applied. The dimensions may be from an inch or less, in length, to several feet, and the tube may be of uniform diameter, and straight; or it may be enlarged into bulbs or globes, with chambers of any form, and it may be coiled upon itself in any way so as to develop the largest amount of light possible within the smallest space. At two points, some distance from each other, two electrodes are fused into and through the glass so as to project into the cavity of the tubes, and at some point a tubulure is formed at the blast-lamp adapting the tube to be attached to the air-pump for exhaustion. The tube so exhausted, to any degree which may be desirable, is hermetically sealed, so as to preserve the vacuum produced. Not infrequently the platinum wires or electrodes terminate in the interior in aluminium prolongations, plates or surfaces suited to develop some peculiar action, when the tube is in operation.

A Geissler tube is operated by joining its electrodes so as to complete the circuit of an induction coil, electrical machine or battery consisting of many cells joined in series. When in operation, the tube is illuminated by the passage of a current, and the character of the illumination depends on the residual gas which the tube may contain, after having been more or less perfectly exhausted by the use of the pump. The character of the light, in other words, depends upon the nature of the gas, and on the degree of exhaustion to which the tube has been subjected.

One of the most important uses of the Geissler tube is the aid which it furnishes us in spectroscopic researches; thus the lines which the spectroscope exhibits when a Geissler tube containg a trace of hydrogen gas is used to illuminate its slit, are found to be identical in character and position with those which are found when the solar atmosphere is made to illuminate the slit. We therefore infer the presence of hydrogen in the solar atmosphere. Some special forms of Geissler tubes have been proposed, and perhaps to some extent used, in surgery, to light up the interior cavities of the human body. They have been proposed for use in mines, and for use in the hands of the diver in submarine exploration.

6 Q. Dr. Morton, in answer to 15 Q., of his deposition given for the defendant, says that the Geissler tube lamps, proposed for miners' use, for submarine

lighting and for surgical purposes are properly included in the general definition "incandescent electric lamps." Do you agree with Dr. Morton in this opinion?

A. I do not; I understand an incandescent electric lamp to be one which emits its light in virtue of the continuous high temperature which it attains while operated by the electric current, which flows through the incandescent portion precisely as it would flow through any other conductor offering the same continuous and steady resistance. The comparatively feeble light given out by a Geissler tube in operation appears to be due entirely to the disruptive passage of electricity from one electrode to another through the intervening gaseous medium. The temperature of the gas does not appear to be raised to that degree which would enable it to become luminous in the same way that the incandescent solid of the incandescent lamp proper becomes luminous. I think it is only in a very loose and general sense that a Geissler tube could be spoken of as an incandescent lamp.

7 Q. In answer to 16, 17, 20 and 22 Qs., Dr. Morton gives several characteristics of Geissler tubes as also being characteristic features of the modern incandescent electric lamps. Do you agree with Dr. Morton in these matters?

A. In respect to many of the characteristics mentioned by Dr. Morton I quite disagree with him, and especially call attention to the following points:

In the answer to 16 Q. at folio 4974, Dr. Morton says: "It develops light by the resistance which it encounters in passing through the trace of gas left in the tube in the process of exhaustion. This gas constitutes a high resistance conductor between the two wires by which the current enters and leaves the tube;" Dr. Morton here treats "the trace of gas left in the tube in the process of exhaustion" precisely as if it were what is recognized as an ordinary conductor of electricity, and he further expressly affirms in the succeeding sentence the same fact more positively. "This gas constitutes a high resistance conductor between the two wires." It seems to be his idea that this residual gas is the equivalent of a wire or other solid conductor, and may be so treated. Now, it is a well-known fact that the gases are perfect non-conductors of electricity. Thus Maxwell, Elementary Treatise on Electricity, 1881, p. 116, says:

> "It is probable that if we could support an electrified body on a perfectly insulating stand, so that it could lose its charge only by conduction through the air, it would never lose its charge."

This is a conclusion which he draws from carefully conducted experiments set out at pp. 115, 116, but which are too long to be quoted.

So, too, Gordon, Electricity and Magnetism, Vol. II, 1880, p. 82, says:

> "This shows that the discharge (in a Geissler Tube) is not a case of true conduction, but that, even at the lowest pressure, it is disruptive."

This implies that the gas cannot be considered as a conductor. Its luminosity must therefore be due to some other action than that of heating a conductor to incandescence.

Also Lodge "Nature," Vol. XXXVII, p. 12, (1887):

> "There is no true conduction to either gases or vapors; in other words, a substance in this condition seems to behave as a perfect insulator—perhaps the only perfect insulator there is. Not even mercury vapor is found to conduct in the least."

And a large number of other authorities might be cited to the same effect. Indeed it is no longer an open question, that the gases and vapors are to be regarded as insulators in the strictest sense.

Indeed the fact mentioned by Dr. Morton in answer to 16 Q., fol. 4975, that "the light produced is of different colors, according to the character of the gas present" is wholly incompatible with the idea that

such light is due to the proper incandescence of a conducting body. For if the light were due to a proper incandescence of the conductor, the character of the light would depend only upon its temperature.

Adjourned for lunch.

Resumed after lunch.

Answer to 7 Q. continued:

It is believed upon good and sufficient evidence that the light produced in rarified gases, as in Geissler tubes, is due to the encounters of the molecules as they act to carry electricity from one point to another by convection, these encounters originating the disturbance in the ether which we recognize as light.

The conclusion reached by Dr. Morton in answer 16, appearing at fols. 4978 and 4979, appears, in view of what has just been said, to be wholly untenable. It cannot be admitted that the light in the Geissler tube is produced "in the same way as it is in those incandescent lamps in which a thin strip, thread or wire of solid material is employed."

If Dr. Morton were right in the conclusion which he expresses, Ohm's Law should be strictly applicable; in other words there should be a gradual fall of potential from one electrode to the other, and the amount of it should vary with the strength of the current flowing through the circuit; which conclusion is not justified by experiment. (See Gordon's work before referred to, p. 81.)

In his answer to 17 Q. Dr. Morton makes a statement, which is true enough, that the capillary bore of some Geissler tubes is even smaller than the incandescent carbon of some incandescent electric lamps. But this fact affords no basis of comparison between the two, since their modes of operation is entirely different, as I have shown before.

In his answer to 20 Q., Dr. Morton treats the Geissler tube as if the gaseous medium whi·h it contains were a conductor, in the proper sense of the term; whereas the fact is, as I have before stated, that the gas is not a conductor at all, and that the passage of electricity from one electrode to another takes place disruptively, the molecules of gas being charged with electricity which they transmit by a process called "convection."

It may be added that in many forms of Geissler tubes the luminous effect is heightened or modified by the employment of peculiar kinds of glass, or by surrounding portions of the tubes with liquid solutions, or by bringing into their proximity gems, minerals or chemically prepared substances which possess the property of fluorescence; that is to say, which can modify undulations of short period so as to render them visible, and thereby increase or modify the light which otherwise would be emitted. In these cases it cannot be contended that the increase of the light is due to incandescence proper, since it is not accompanied by or dependent on any rise of temperature, above that which would be evolved by the simple passage of the current through the conducting gas, if we admit for a moment that it is a current and that the gas is a conductor.

In answer to 22 Q. Dr. Morton says, in effect, that it is as appropriate so call the line or thread of gas which constitutes the source of light in a Geissler-tube lamp a burner, as it would be so to call the carbon or platinum which is used as the source of light in incandescent lamps. I quite agree with Dr. Morton that the only appropriateness of the team "burner," as he uses it, is the fact that the object to which it is applied is the source of light from which the light radiates—in which respect it resembles the "burner" of an ordinary lamp or gas fixture. But I entirely repudiate the idea that this constitutes any good reason for the conclusion that the construction and mode of operation of a Geissler tube is such as to render it in any way comparable with the construction and operation of an incandescent lamp, in which a solid incandescing conductor is employed.

I am not aware that the term "burner" has ever been applied to a Geissler tube in any scientific description. The term "burner," if used in connection with either an incandescent lamp or a Geissler tube, must be employed in an extremely vague and general sense, and we ought not to be misled by its use into forming any comparison between the objects to which it is applied.

8 Q. I hand you a paper marked "Notes on Geissler Tubes," consisting of citations from various authorities. Have you verified these citations.

A. I have verified all the citations of this paper except one, viz: Mascart, Elec. Stat. II., 150, 1876. This reference was not at hand and consequently I have thus far been unable to verify it.

> Complainant's counsel offers in evidence the paper referred to, and the same is marked Complainant's Exhibit Notes on Geissler Tubes.
>
> The introduction of this exhibit objected to unless the context of the various extracts constituting the exhibit is also produced and put in evidence.

9 Q. Dr. Morton in 18 A. says that Geissler tubes constructed for the purpose of illumination have been made and sold commercially for at least twenty years. Is that statement correct, as you understand the meaning of the word "illumination"?

> Question objected to unless the witness shall make it appear that he has as full information upon the point inquired about as Dr. Morton had when he gave that answer.

A. It is doubtless true, as Dr. Morton says, that Geissler tubes have been made and sold for the last twenty years commercially; that is to say, they have been manufactured and supplied for cabinets of physics, to those engaged in spectroscopic work, to lecturers for public exhibitions, etc., but not for purposes of general illumination, understanding by the term "illumination" the lighting of interiors of dwellings, public buildings, streets and thoroughfares. I have myself been a student of applied electricity for more than twenty years, and am reasonably familiar with the appliances in use and with the literature upon the subject, and I have no recollection of such apparatus having been employed for purposes of general illumination. In support of my belief that such is not the case, I call attention to the fact that in general those authors who have set forth the history of the progress of electric illumination have not mentioned the Geissler tube as one of the means to be employed. This is true, I believe, of Prescott, Sylvanus Thompson, Gordon, Schellen, Sawyer, etc. By way of showing the inferiority of the Geissler tube as a means of illumination, I quote from Paget Higgs' translation of Fontaine's Electric Lighting (1878), p. 1:

> "The electric light may also be produced by the use of Geissler's tubes, but the feeble lighting power of these tubes renders them unsuited to domestic or industrial uses."

It is true, however, that for special purposes of lighting a very limited area, such as would be involved in the examination of the bottom of a ship under water, or surgical examination of the cavities of the human body, the Geissler tube has been to a limited extent employed. A proposition has been made to apply the Geissler tube to the lighting of buoys, "but this kind of light is so low in intensity that it appears to us to be qutite difficult to apply it advantageously to this subject." (See Defendant's Exhibit Translation Du Moncel's Article on Geissler Tube Lamps, p. 2078, fol. 8312.) Also in Defendant's Exhibit Translation Wilde's Report on Lodyquine Lamp, p. 2113, fol. 8449, it is said. "Geissler tubes have been proposed for the division of the electric light, but experience has shown that this light was too feeble and not constant enough."

I also quote from Fontaine in the translation referred to, p. 168, *et seq.*

> "It has been endeavored to use Geissler Tubes and small incandescent carbons, and if these means have not been successful, they offer, nevertheless, sufficient interest that we devote several pages to their description. * * * Light obtained by the Geissler Tube is so feeble that it can never be used practically, and numerous trials made in mines and powder mills have been without result."

10 Q. What is the value of Geissler tubes, in your opinion, for general illumination?

A. I should say that for such purposes they are practically useless, the light being altogether too feeble, and the means of operating them altogether too expensive.

11 Q. Were the principles involved in the construction of the Geissler tube, namely, the continuous glass chamber and the platinum wires fused into its walls, applicable to the construction of the chambers of the incandescent electric lamps known prior to Mr. Edison's work upon this subject? Kindly give your reasons for any opinion you may express?

A. I should say the principles involved in this mode of construction were not applicable to the lamps in question. Such lamps were constructed with a view to obviating the difficulties attendant upon their short life, which resulted from the wasting away or breaking down of the incandescent burners which they enclosed. They were, therefore, so constructed that, on the failure of a lamp to operate by reason of the destructive action of the current, they might be taken apart so as to allow the renewal of the incandescent body. This implied the use of a glass chamber fitted to and cemented upon a suitable base, in which case it was impossible to maintain a suitable vacuum, or the use of the so-called Torricellian vacuum, in which was contained the incandescing body, in which case the vacuum was produced and maintained by the use of the mercury column. In any case they were so constructed that the wasted or destroyed parts might be renewed as occasion should require. This general idea is incompatible with the employment of small, hermetically-sealed glass enclosures, with platinum electrodes fused into their walls. The one plan contemplated the renewal of the incandescing body from time to time; the other involved the abandonment of the entire structure when its period of usefulness was passed.

12 Q. Are you acquainted with the English Patent of King No. 10,019, of 1845?

A. I am.

13 Q. How perfect a vacuum would the method proposed by King produce, and how effective would such a vacuum be in use?

A. The vacuum could not be very perfect for the reason that considerable quantities of air would be found adherent to the walls of the tube and the structure of the lamp itself, and would be absorbed and held by the incandescing carbon until expelled by the operation of the lamp. Enough air would be contained in the lamp, I believe, to act injuriously upon it and insure the destruction of the incandescing carbon.

Adjourned until Wednesday, July 16, 1890, at 11 A. M.

New York, July 16, 1890.

Met pursuant to adjournment.

Present—G. P. Lowrey and R. N. Dyer of Counsel for Complainant, S. A. Duncan of Counsel for Defendant.

Direct Examination of the Witness, Prof. Brackett, continued:

14 Q. Dr. Morton, in answer to Qs. 34 and 35, expresses the opinion that the statement contained in the King patent that "when the apparatus is suitably sealed, it may be applied to submarine lighting" etc., means that the bulb of the King lamp is to be sealed off by fusion above the mercury column so as to form a lamp chamber substantially such as is employed in the modern incandescent lamp. Do you agree with this view of the matter? Kindly give your reasons for any opinion you may express.

A. I cannot agree with Dr. Morton in the opinion which he expresses, as will be evident when I state the following reasons:

First, the lamp, as described in the specification and shown in the drawing, is so constructed that the incandescing portion of the lamp, together with its fixtures, may be unscrewed and removed from the lamp chamber—as is evident from the following quotation:

> "A binding-screw is fixed on the top of the wire, whose lower end screws in the iron piece *d*, to this piece the forceps *f*, are attached, and it is connected with a similar piece at *h* by the procelain rod *i*. The forceps *g* are attached to *h*, and clamp the lower end of the carbon piece *c*, which has its upper end held by those at *f*, *n* is a copper wire which is fixed into the piece at *h*, and extends to the bottom of the tube, the tube is filled with mercury in the same manner as a barometer, the usual precautions being taken to expel the air; its length independent of the bulb should be about 30 inches, so that when it is inserted in a cup of mercury a vacuum will be formed in the bulb."

If a lamp having such construction could be sealed by fusion in the way supposed by Dr. Morton, it is clear that it could not be a useful lamp, in that it could not be kept in continuous operation for any considerable time; for, as already stated in this deposition, the vacuum in such a lamp would be too incomplete to admit of its being long serviceable.

But, second, a lamp having the construction described and shown in the patent could not be sealed at the lamp, as is now done with incandescent lamps, because the quotation already made in this answer shows that a copper wire is fixed into the piece *h*, which is situated in the lamp chamber, and extends to the bottom of the tube. Now any attempt to seal off a tube through which a copper wire passes, so as to leave an air-tight joint around the wire, must inevitably fail, since the co-efficients of expansion for glass and copper are greatly different—so much so indeed as to make it certain that, if the proper fusion be effected, the glass will break on removal from the blast-lamp.

Third, the necessarry thickness of the walls of the tube which could be safely employed to produce the Torricellian vacuum, and at the same time give the necessary strength to the apparatus, would be such as to render fusion at the blast-lamp, supposing it were otherwise possible, very difficult—so much so as not to be a practicable operation.

And, lastly, nothing is said in the specification or shown in the drawing which indicates that the tube by means of which the vacuum is produced is to be reduced in length beyond that stated, viz: about 30 inches.

15 Q. Please explain how the quotation you have given from the King patent shows that the incandescing portion of the lamp, together with its fixtures, may be unscrewed and removed from the lamp chamber; and what would be the purpose of such a construction?

A. In order to answer this question I call attention to the language "whose lower end *screws* (the italics are mine) into the iron piece *d*." Now, reference to the drawing makes it clear that the lower end referred to is that of the stout platinum wire fused into the end of the lamp chamber. It is hence evident that the incandescing carbon *c*, together with all the supporting apparatus, is attached to the lower end of the platinum wire by a screw joint. It may therefore be unscrewed and removed, if any suitable means are provided for that purpose. The quotation shows that such means are provided, for the copper wire *n*, which extends

downward through the tube, is shown and described as *fixed* into the piece *h*.

> "*n* is a copper wire which is fixed into the piece *h* and extends to the bottom of the tube."

It is quite clear that the incandescing carbon and its supports may be introduced into the lamp chamber, or removed from it, by simply employing the copper wire *n* for that purpose. In further confirmation of this view, I call attention to the fact that the tube which is joined to the lamp chamber proper is shown in the drawing of sufficient width to allow the introduction or removal of the carbon and its support.

I take it that the purpose of this construction is to allow the user to replace the carbon from time to time, as it shall waste away or be destroyed under the action of the current, or otherwise injured. In short the lamp appears to be constructed with special reference to renewal of its carbon, which from its imperfect character must frequently become necessary.

16 Q. I call your attention to the fact that Fig. 2 of the drawing of the King patent shows the lower tube slightly smaller than the cross-pieces *d h* which are attached to the forceps *f g* which hold the carbon. Does this fact change your opinion that the King lamp is designed to have the parts withdrawn through this tube?

A. It does not, for if the active portion of the lamp were designed to be a fixture which could not be removed from the chamber, no useful purpose could be subserved by the screw-joint which unites the iron piece *d* with the platinum wire. Nor would there be any necessity for the tube which is employed to produce the vacuum in the lamp chamber being so large as is shown in the drawing. The excess of the length of the cross-piece *h* over that of the diameter of the tube is so slight that it had escaped me in making my previous answer, and I have no doubt that it is wholly due to an error of the draughtsman.

17 Q. Are you acquainted with the various forms of

the Crookes radiometer referred to in the deposition of Prof. Cross, and to what extent?

A. I am familiar with the apparatus, having in my possession specimens of radiometers essentially the same as those described by him and shown in the drawings given in his deposition, though slightly different in form. I have frequently employed them for the purpose of showing the mechanical effects due to the movement of highly rarified gases under the influence of radiation.

18 Q. What is the Crookes radiometer used for, and what especially is the purpose of the continuous platinum wire enclosed in some forms of the apparatus?

A. The radiometer of Crookes is employed to show the mechanical effects due to the molecular encounters which take place in gases when in a very rarified condition. These mechanical effects may be shown in a very simple way by suspending a light, thin body, as a plate of mica, of which one side is blackened, on a delicate spring within an air chamber which can be very completely exhausted. It will be found that if a luminous body, or one which is emitting radiations, be presented to the plate of mica situated as just described it will be displaced from its position. If several thin disks of mica be mounted so that they can turn about a perpendicular axis, as shown in Fig. 30 or 31 of Prof. Cross' deposition (p. 1811, fol. 7242 printed record), continuous rotation will result. The radiometers, in one form or another, are designed and adapted to show such mechanical effects as produce rotation or displacement, and which have their origin in the molecular encounters of rarified gases.

The continuous platinum wire is designed to be joined to a battery or other source of electrical energy so as to become heated thereby, and thus effect the radiation required to operate the radiometer.

19 Q. Prof. Cross in his deposition for the defendant expresses the opinion that, from the knowledge extant in 1878 as to the construction of Geissler tubes and Crookes radiometers, if a person constructing one of the old carbon incandescing lamps having a separable lamp chamber had found it to leak he would, as a matter of course, have made the lamp chamber of a continuous piece of glass, with platinum wires sealed into it by fusion; do you agree with Prof. Cross on this matter?

A. All that I know of the subject would compel me to disagree with Prof. Cross, for it seems to me that if he were right some one would actually have done this very thing. It is perfectly clear that with the knowledge and experience which we now have the process of sealing would have been resorted to by any competent person constructing an incandescent lamp had it not been for the fact that he would have been influenced to do otherwise by the necessity of having a lamp in such form that the incandescent carbon could from time to time be renewed, which condition is incompatible with hermetical sealing.

20 Q. Are Crookes radiometers now used, or have they ever been used for electric lighting?

A. In the proper sense, no.

21 Q. I call your attention to Complainant's Exhibit Dr. Morton's Published Test of an Edison Horseshoe Lamp, and to the conclusion reached by him as to what he calls the trifling economy over gas. Was the state of the art such as to warrant a more favorable conclusion as to the economy of incandescent electric lighting by Edison lamps, compared with gas lighting, than that given by Dr. Morton?

Objected to as immaterial.

A. I think it was, and in support of that opinion I call attention to the assumption of Dr. Morton found in the paper referred to, in which he says:

> "Assuming that a Brush or a Siemens machine were employed to generate the electric current, such a current would be obtained, as has been shown by numerous experiments, with a loss of about 40 per cent. of the mechanical energy applied to the driving-pulley of the machine."

That this is too low an estimate of the efficiency of the machine is clearly shown by the experimental tests made about the same time by Prof. Young of Princeton and myself, of an Edison dynamo-machine. These tests were published in the American Journal of Science, Vol. XIX., June, 1880, and they show that the available efficiency of the Edison dynamo-machine at that time was not less than 78 per cent. This being so, a more favorable result than that which Dr. Morton has made was already attained for incandescent electric lighting at that date.

In Dr. Morton's comparison of electric incandescent lighting with gas-lighting, he makes no allowance for the loss of gas by transmission through the pipes to the burner. This fact makes the case less favorable for electric lighting, as compared with gas lighting, than it should have been.

Taking these circumstances into account it does not appear to me that Dr. Morton is justified in the use of the language in the paper referred to. "This relatively trifling economy disappears, or ceases to have any controlling importance in the practical relations of the subject." At the date of the paper referred to there was undoubtedly a positive and very considerable advantage in favor of electric lighting, as compared with an equal amount of illumination by gas, when recourse was had to the most efficient dynamos, with properly arranged lamps and lamp circuits.

Complainant's counsel offers in evidence the paper published in the American Journal of Science referred to by the witness, and the same is marked Complainant's Exhibit Brackett-Young test of Edison Dynamo.

Adjourned for lunch.

Resumed.

CROSS-EXAMINATION BY GEN. DUNCAN:

22 x-Q. Have you any evidence other than what you have already set forth that the inventor of the King lamp intended to make the carbon supports removable from the lamp bulb?

A. I know of no positive statement that such was his intention, but I think that is a fair inference from the description which the inventor gives in his specification, and from examination of the drawing which accompanies it, as well as from the state of the art of electric lighting at the date of this specification. The conviction that such was his intention which arises from examination of his patent, and from the state of the art, is strengthened by the fact that no descriptions of incandescent lamps otherwise constructed are to be found, so far as I recollect, prior to 1845, the date of the patent.

23 x-Q. What description of incandescent lamps do you know of, prior to the year 1845?

A. None occur to me, save such as were adapted to be used without being enclosed in a glass chamber; and these, so far as I can recollect, employed a platinum or other metallic body for the incandescent substance, or were semi-incandescent lamps, if such they might be called, in which the illumination arose from the highly heated condition of pencils of carbon in contact, and were only experimental in character.

24 x-Q. Am I right in assuming that you are of the opinion that when the King patent uses the word "fixed" in describing the connection between the copper wire *n* and the cross-piece *h*, the draughtsman of the specification intended to exclude the use of a screw-joint connection between those parts?

A. Not necessarily. I suppose the intention was to indicate that the copper wire *n* was to be so permanently united to the piece *h*, in any suitable manner, that the illuminating apparatus could be screwed to the lower end of the platinum wire which is fused into the upper portion of the lamp chamber. It is evident that this might be accomplished by tightly screwing the copper wire *n* into the cross-piece *h*, or by riveting, or soldering, or any other convenient way. The words "fixed into the piece at *h*" leave the method of fixing undetermined.

25 x-Q. Do you regard it as an essential feature of the King invention that the lamp be so constructed that the burner and its supports can be readily removed from the bulb; by "essential feature" I mean is the construction so characteristic of the King invention that a lamp not having such a feature would not be a King lamp, even though in all other respects it were confessedly like the lamp shown and described in the King patent?

Objected to as immaterial and indefinite.

A. Considering the state of the art of incandescent lighting at the date of this patent, I should consider it an essential feature; for in my belief the inventor was careful to provide a means which would permit the renewal of the active portions of the lamp from time to time, as should be necessary. For, as already shown, the period of active usefulness of such a lamp could not be very great. I do not mean to say, however, that a lamp constructed in all respects like the King lamp, with the exception indicated in the question, would be an inoperative one, for a short time. King's endeavor was plainly to provide an apparatus in which a renewal of the incandescing portion might be made without incurring the expense attendant on an abandonment of the entire structure when the incandescing portion should fail.

26 x-Q. If that was his chief, or one of his principal ideas, does it not seem to you somewhat singular that he should not have stated it in more explicit language, and particularly have shown in the drawing a structure which would have permitted of the removal of the carbon supports?

A. I do not suppose that a detail of construction

formed the chief object in the construction of the lamp. On the contrary, the principal or chief object is secured when an incandescing body is provided and suitably connected, so as to be traversed by the current. In order, however, to render this available, and secure the greatest usefulness for the lamp, provision is made, as I have pointed out, for the convenient renewal of the incandescing carbon. And this is explicitely described in the language which I have already quoted, and to which I have called special attention. The necessary manipulations to secure the vacuum are such as would be well known to any one who was shown the apparatus; and the description of its construction is in general of a character not different from that which would be given of any apparatus which was to be used for the production of a vacuum such as is contemplated in this lamp. I should not, therefore, expect the patentee to insist upon or point out the necessity of using the apparatus and adjustments which he describes, since they would be quite evident to any one familiar with the art and to whom the apparatus should be shown. The fact that the draughtsman has made no special endeavor to show in detail the screw at one point and the mode of fixing the copper wire at another is I think due to the fact that he has attempted only what may be called a diagram of the apparatus, designed merely to show the relative positions and general character of the parts entering into its construction.

Adjourned until Thursday, July 17, 1890, at 11 A. M.

New York, July 17, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

Cross-Examination of the Witness, Prof. Brackett, continued:

27 x-Q. If King had had distinctly in mind the re-

movability from the lamp bulb of the parts which support the carbon burner, would he not naturally have shown the small tube at the base of the bulb in figure 2 of his patent of a diameter sufficiently large to permit such a removal to take place ?

A. One would naturally think so, but as I have already stated, in my view the figure to which reference is made is merely diagramatic; and the fact that the tube at the base of the chamber is of slightly less diameter in the drawing than would be required for the removal of the parts which support the carbon burner is probably an error or inadvertence on the part of the draughtsman. This, however, does not prevent me from entertaining the belief that the patentee intended the removal of the parts in question, since otherwise no useful purpose would be subserved by the particular manner in which the parts are constructed. I have reference to the fact that the specification distinctly describes the junction of the platinum wire as being made by means of a screw; while that with the copper wire is referred to as being "fixed."

28 x-Q. So far as the drawing alone is concerned, it is an argument against your position, is it not ?

A. At first sight it might appear so; but, on consideration, I think it is an argument in favor of my view, and particularly that an error has been made in constructing the drawing; for, otherwise, it would need to be explained why the tube at the base of the chamber is shown of so large a diameter as it is. Evidently a much smaller tube would subserve the purpose of exhausting the chamber equally well, would render the construction of the lamp less expensive, and facilitate its portability, since less weight of mercury would be required to fill it.

29 x-Q. How small a tube would have answered, if it had not been for this assumed capacity of removing the internal parts of the lamp ?

A. The tube need not have been of diameter more than just sufficient to allow the free movement of the mercury in the tube and past the copper wire which it contains. It would therefore depend on the size of the

wire employed. If this were, say, $\frac{1}{8}$ inch in diameter, the tube need not be more than $\frac{1}{4}$ inch internal diameter, or even less. Some light on this question may be obtained from the consideration that signal-service barometer tubes are frequently employed not more than $\frac{1}{4}$ inch in diameter.

30 x-Q. By the rule laid down in your last answer, would you not consider the mercury tubes in the lamp shown in Edison's Patent No. 237,732 unnecessarily large?

A. Not necessarily; for the tubes shown in the patent referred to subserve a double purpose, viz.: first, to exhaust the chamber, and second to act as conductors to carry the current to and from the incandescing carbon. And the patentee uses the following language with reference to them:

> "The columns C, C′ should be of such diameter as to give no greater resistence to the circuit than does either of the conductors c, c', 2 or 3."

Now, since mercury is a poorer conductor than those designated as 2 or 3, which are presumably of copper wire, it is manifest that the mercury columns contained in the tubes C or C′ must be of considerable size to avoid undue heating by the passage of the current through them.

31 x-Q. Do you then think that the fact that the mercury column forms a part of the circuit in the Edison lamp referred to sufficiently accounts for what would otherwise seem to be the unnecessarily large size of the tube in which the mercury is contained ?

A. It would certainly be a sufficient reason for making them of considerable size that the patentee wished to avoid a development of heat in them, so as to be able to utilize it in the incandescing conductor B. So far as exhausting the chamber is concerned, they certainly need not be of diameter greater than just sufficient to allow the free passage of mercury to and from the chamber, so as to remove and exclude the air from it.

32 x-Q. Is it not possible that King made the mercury tube of his lamp considerably larger than was necessary for the mere purpose of exhausting the bulb, for the same reason that you have given for the enlarged tubes of this Edison lamp; in other words, in the form of King lamp shown in Fig. 2 of the King patent was not the mercury to form part of the circuit, and if so, was not that a good reason for making the tube larger than was required merely for exhausting the lamp, even though it were not made large enough to permit the withdrawal through it of the internal parts of the lamp?

A. I do not think so, for, otherwise, I can see no use for the introduction of the copper wire *n*, which is "fixed into the piece at *h*, and extends to the bottom of the tube," especially if we assume that the internal parts are not to be withdrawn through the tube, or introduced through it, which assumption, I take it, is implied in the question. The copper wire *n*, in my opinion, serves—indeed it cannot but serve—as the principal and most efficient conductor of the current through the tube, although it is true, of course, that the mercury will act to convey a part of the current, which will traverse both it and the wire in accordance with Ohm's law.

33 x-Q. Do you not find that the King patent expressly states that one of the wires from the battery "passes into the mercury in the cup at the bottom of the tube. The circuit is thus completed by the column of mercury"?

A. Certainly. And this, I take it, is an application of the well-known method which was early employed by electricians of joining an electric circuit by means of "mercury cups." This was the almost universal method in early practice of "joining up" electric circuits, since it could be done with great facility and completeness. It is evident that in such an apparatus as the King lamp no better construction or provision of a mercury cup could be made than that which the exhausting column of mercury in that lamp offered.

34 x-Q. You made a deposition, did you not, in the

suit lately decided in the U. S. Circuit Court for the Western District of Pennsylvania brought by the Consolidated Electric Light Company against the McKeesport Light Company for the infringement of the Sawyer-Man Patent No. 317,676 of May 14, 1885?

A. I did.

35 x-Q. Is the following a correct transcript of x-Qs. and As. 81–87 of your deposition in that case, and do you still entertain the views which you then and thus expressed:

"81 x-Q. In your answer to question 4 you refer to the English Patent of King No. 10,919 of 1845, and quote from the specification the paragraph relating to the use of the lamp for submarine lighting. What do you understand by the expression "when the apparatus is suitably sealed" used in this paragraph?

A. I understand if in case an incandescent conductor of carbon, which is liable to be consumed if oxygen be present when it is in action, were employed in the construction of a lamp, and if in such lamp a vacuum were produced and it were heremetically closed, then such a lamp might be used in submarine lighting.

82 x-Q. What do you mean by "heremetically closed"?

A. I mean the same thing as is to be understood by the language "suitably sealed." Those are the words that the patentee uses. By closing I mean sealing.

83 x-Q. Do you understand this paragraph quoted to refer to any different construction or further sealing of the lamp than is shown in figure 2 of the patent and described in the part of the specification preceding this paragraph?

A. There is nothing in the patent by which this question can be decided, I believe. In the structure shown a platinum wire enters the top of the illuminated chamber; and is sealed to the glass constituting it in the usual way, I suppose. But the connection with the electric conductor at the "bottom is to be made through a copper wire which communicates with the lower end of the incandescent carbon rod. When the Torrecellian vacuum is made as is pointed out in the patent it is not easy to see how the same sort of seal can be made at the lower extremity of the lamp, for it is manifestly impossible to fuse the glass and the copper wire together so as to effect that purpose. It appears, therefore, that some other sealing than that alluded to in the question or at least some other arrangement for closing the tube than would be employed in simply fusing the glass and lower conductor together is contemplated by the patentee.

84 x-Q. Would it be practicable to use the lamp for submarine lighting with the mercurial seal such as used in barometers?

A. It would be entirely possible to use such a lamp. It certainly would not be a very convenient one.

85 x-Q. Would it, in your opinion, require any invention to use a platinum wire for the lower connection and seal it into the glass in the same manner in which the upper wire is sealed into the glass?

A. Probably not.

86 x-Q. The art of sealing platinum wires into glass so as to obtain a tight joint has been well known in the art for forty or fifty years, has it not?

A. It has.

87 x-Q. In what classes of apparatus had such a joint between glass and platinum been used prior to 1880?

A. It had been used in the construction of eudiometric apparatus for the analysis of gases, in some forms of electrolytic apparatus for decomposing liquids, and, somewhat more recently, in the construction of vacuum apparatus, Geissler tubes, &c., but prior to 1880."

A. I have no doubt that is a correct copy. I still entertain the views then expressed.

36 x-Q. In the year 1845 was the Torrecellian vacuum regarded as the best attainable vacuum for practical purposes?

A. Not as originally given by Torrecelli himself.

37 x-Q. With the improvements made upon his original method, was it the best practical mode then known for producing a vacuum, in the industrial arts?

A. Understanding by "improvements" to be included the methods of carefully cleaning the tubes, sufficiently boiling the mercury in them, with proper agitation to exclude every trace of air, I should say it was.

38 x-Q. You refer now, I suppose, to improvements that were known in 1845?

A. I do.

39 x-Q. Are you familiar with the historical accounts of the trial of the King lamp, as made in 1846, in England, in the presence of Faraday and others?

> Objected to as immaterial and as incompetent, since the "historical accounts" themselves if any such were ever published, are the best evidence.

A. In a general way, yes. I have not in mind, however, at present, the details of those experiments.

40 x-Q. Do you recall the circumstance that at one or more of those exhibitions King used a chandelier with thirty-six lamps upon it, each one representing one of the United States of America?

> Same objection.

A. I do not.

41 x-Q. Do you recall the fact that Faraday warmly commended King (or perhaps Starr, the inventor), for

the performance of these lamps at the time of the exhibitions referred to?

Same objection, and further as indefinite, because it does not appear whether it is the carbon or the platinum lamp of King which is referred to by the question, or whether, if the former, it is like the carbon lamp described in the King patent or an entirely different structure.

A. I do not.

42 x-Q. Referring to the Geissler tube, if every trace of air or gas should be removed from the tube, if this were possible, could the electric current be made to pass through the vacuum?

A. I suppose not. It is not very difficult to produce such complete exhaustion as to preclude the passage of the spark from a quite large induction coil.

43 x-Q. Then in the Geissler tube as ordinarily constructed, the presence of the gas contributes in some way and to some extent to facilitate the passage of the current, does it not?

A. Undoubtedly it does.

44 x-Q. Given two Geissler tubes, one very highly exhausted, and the other with a low exhaustion, in which will the current pass the more readily?

A. The question is, I think, best answered thus: If a single tube be fitted with its electrodes, and attached to the exhausting pump, or other device, for removing the air or gas, and joined up in circuit with the induction coil or electrical machine, and the induction coil be put at work, and kept so while exhaustion progresses, it will be found that the spark passes with greater facility as the exhaustion proceeds toward completion, up to a certain limit, beyond which it experiences greater and greater difficulty, and at last fails to pass at all. If, therefore, of the two tubes referred to in the question, the one were very highly exhausted, a point might be reached at which the passage of the spark through it would experience substantially the same difficulty in passing as through the other, which was only moderately

exhausted. The effects, however, displayed by the two tubes in the two cases, supposing them originally filled with the same gas, would be quite different. It would seem, therefore, difficult to answer the question explicitly by saying which of the two tubes referred to in it would admit the readier passage of the current, unless the degree of exhaustion in either case were known, and reference had to experiment by which this might be determined.

45 x-Q. At what point in the process of exhausting the tube, does this observed change in the law of the resistance of the contained gas take place?

A. I believe it depends to some extent upon the nature of the gas, and is only found after the exhaustion has proceeded to a pretty high degree, which I can not exactly name at this moment.

46 x-Q. Is it not probable that the fall in resistance during the early stages of exhausting a Geissler tube is due to the heating of the gas when the current passes?

A. If by "heating" we are to understand the same thing as is meant by heating a solid, every part of which is raised at the same time to a high temperature, I unhesitatingly answer no. That there is heat developed by the successive encounters of the molecules constituting the path of the electric discharge, which takes place disruptively through the gas, is probably true. That the fall of the resistance is due to the development of heat is hardly probable, for several reasons: First, there is no fall of resistance in the proper sense of the word, since the discharge takes place in a manner wholly different from that which is found in the passage of a current through a solid conductor. The greater facility with which a discharge takes place in the earlier stages of exhausting a Geissler tube is more probably due to the increased mean free path of the molecules, which transmit the electric energy by convection.

Adjourned for lunch.

Resumed.

47 x-Q. You have used the term "convection," as descriptive of the mode by which the electric current passes through the rarified gas of a Geissler tube. Please explain a little more fully what you mean by this term?

A. This is best done by pointing out what is understood to be the difference between "convection" and "conduction." Energy is said to be distributed by convection when the molecules of the medium through which the distribution takes place are disturbed from the positions which they otherwise would maintain by movements through distances which are very considerable in comparison to their size; and the nature of the movement is in general such that no fixed form of the body constituting the medium would be maintained, except as it is enclosed within limiting walls or surfaces, such as are employed for containing gases or liquids. Conduction, on the other hand, is quite compatible with such minute movements of molecules as do not greatly take them out of their mean position; hence, the character and form of conducting bodies remain permanent or substantially unaltered.

48 x-Q. Then, as I understand you, there is always a molecular disturbance in the passage of the electric current, and you apply the term "convection" when this disturbance becomes very great, as in the case of a gas, and the term "conduction" when the amount of the disturbance is very much less, as in the case of a solid. Does this correctly state your view?

A. Yes, with the addition of the idea that in the case of the gas there is not such cohesive action as would tend to preserve the integrity of its form, apart from the containing vessel or enclosure.

49 x-Q. Is not the difference in the method by which the electric impulse is propagated in the two cases of a solid and a rarefied gas, due to the difference in the molecular constitution of the two bodies, arising from the distance between the molecules and their mobility among each other?

A. Undoubtedly, molecular constitution has much to do with this difference; or, more properly speaking, what is known to physicists as the state of aggregation has much to do with it.

50 x-Q. Do you understand that the term "convection" is properly descriptive of the method by which the electric energy passes through a gaseous body? And if so, why?

A. I do; quite so. I suppose the action by which electric energy is transferred across a gaseous medium is that those particles which are in proximity to the charged electrode on the one hand acquire a similar charge with it, which is conveyed by them across such distance as shall depend upon the state of condensation or rarefaction, to those next adjacent, to be in turn accepted by them and in like manner conveyed by them; and so on, until the opposing electrode is reached, or equalization of potential is secured. And in case continued difference of potential is maintained, such action goes on continuously, but in a manner quite different from that which solid conductors can exhibit.

51 x-Q. Is it not by substantially the same kind of movement of the molecules, but of course through much more limited distances, that electrical energy is propagated through a solid?

A. I should say not, and I give one or two reasons. First, there is very complete evidence that gases do not conduct electricity at all. They are believed to be, and are said to be by the best authorities, perfect insulators. Thus Clerk Maxwell expresses the opinion that in every case where a body charged with electricity loses its charge, it does so by the conducting action of its supports, as will appear by the following quotation. (See Maxwell's Elementary Treatise on Electricity; 1881; page 116.)

"The more perfectly insulating we make this apparatus (which is required to support it), the more slowly does the electrified body lose its charge, so that it is probable that if we could support an electrified body on a perfectly insulating stand, so that it could lose its charge only by conduction through the air, it would never lose its charge."

Other authorities to the same effect might be cited.

Now, if any conducting body supported as in this quotation, and charged however feebly, were joined to earth by a conducting wire, or a carbon rod, it would be discharged in a time that would be practically infinitely short.

Second, the phenomena of stratification, the so-called "dark space," and the "electric glow" and other similar phenomena which are exhibited by Geissler tubes in operation, are wholly at variance with the idea that the passage of electric energy through them is accomplished in any such way as is accomplished in solid or liquid conductors.

52 x-Q. What I intended to ask in the last question was this, whether in the passage of electric energy through a solid the molecules nearest one of the electrodes do not first become electrified with a charge similar to that of the adjacent electrode, and then move toward the more distant molecules, and communicate a charge through such molecules? If this be not the action which takes place in case of conduction, what is the nature of the molecular disturbance which, as you have said, accompanies the passage of the electric current through solids?

A. Several theories have been propounded to explain what goes on during what is called the passage of the electric current. Those who have viewed electricity as a material existence have supposed it to have properties analogous to those of a fluid, it being, however, incompressible. A battery or other means of producing the electric current might, in this view, be regarded as acting in a way quite analogous to the action of a force pump. So that the fluid which is forced into one extremity of the conductor must displace an exactly equal amount of electricity at the other end. In the case of a battery circuit this would result in a continuous circulation of electricity in every part of the circuit. This notion is evidently a very crude one, and was never intended by those who first propounded it to be anything more than a convenient analogy.

Others have supposed that the ether itself, the medium of luminous and thermal radiations, is transferred from one portion of the conductor to another, and this transfer constitutes the so-called electric current.

The most generally received view at the present time is that the electric stress which constitutes the electromotive force, or difference of potential between one point and another, is first set up and established in the ether pervading the insulating medium which surrounds the conducting body. In accordance with this view an electric current is set up in every part of an electric circuit simultaneously, with the exception of the minute difference in time which would be required for the transmission of light from one point of the conductor to another. On this view the only molecular action which is set up in an electrical conductor is thermal, or such as would be due to the action of heat generated in any way. There would still, however, be a distinct difference between the action of gases and solids, as in fact experiment shows that there is.

53 x-Q. In the section of Clerk Maxwell's book, from which you have quoted, does there not occur this statement:

> "The whole theory of the electric properties of gases is in a very imperfect state"?

A. There does.

54 x-Q. Is not the entire section from which you have quoted as follows:

> "The whole theory of the electric properties of gases is in a very imperfect state. According to the kinetic theory of gases, their molecules are in a state of agitation, so that they are continually striking against each other. The velocity of this agitation is greater the higher the temperature. It would appear, therefore, that the electric conduc-

"tion of gases is of the nature of convection. At every collision the whole charge of two of the molecules would be equally divided between them, and thus the tendency of the agitation would be to equalize the charges of all the molecules.

But we can hardly admit a theory of this kind when we consider that we have hitherto obtained no evidence of the conduction of electricity through air at the ordinary pressure and temperture under a feeble electro-motive force.

Whenever a body free from projecting points and sharp edges and charged to a low potential is found to lose its charge, the result can always be traced to conduction through the substance or along the surface of the apparatus which is required to support it. The more perfectly insulating we make this apparatus, the more slowly does the electrified body lose its charge, so that it is probable that if we could support an electrified body on a perfectly insulating stand so that it could lose its charge only by conduction through the air, it would never lose its charge."

A. It is.

55 x-Q. In one of the extracts in Exhibit "Notes on Geissler Tubes," there appears language ascribed to Sir William Thompson, as follows :

> "Air is one of the best, although not the strongest, insulators."

Do you understand by the statement that there are other substances which will insulate more perfectly than air, according to Thompson's conception of the matter?

A. Not at all. What he means is, that a less separation of electrified bodies in air would be required to prevent the passage of a spark of electricity between them, than would be required of some other bodies usually accounted good insulators—glass, shellac, for example. He does not mean at all that, within the limits of stress which air can sustain, it is not a perfect insulator.

56 x-Q. In you answer to 11 Q. you have referred to the alleged short life of the incandescent electric lamps, which were known prior to Mr. Edison's work upon the subject. To what do you attribute that shortness of life; was it due to the imperfection in the manufacture of the burner, or to the leakage of air into the chamber through the joint between the two walls of the chamber?

A. To both of these causes, together with the fact that in the original construction of such lamps no such vacua as would be requisite to secure a long life had been produced. This fact, of course, together with that of leakage, to which the question refers, constitute not inconsiderable defects of such lamps. The want of uniformity in the incandescing carbon would also tend to its speedy destruction.

57 x-Q. It was perfectly well understood at and before that time, was it not, that a very high vacuum was necessary for protecting the burners of such incandescent lamps as employed carbon?

A. Not in the sense in which we now use that term, I think. It was undoubtedly recognized that oxygen must be removed and excluded from the lamp, but it was not so well known that gases, which do not support combustion ordinarily, must likewise be excluded. Nor was there the general idea of what constitutes a high vacuum, as we now understand that term. The means of producing such a vacuum were only at hand when the Geissler and Sprengel pump appeared.

58 x-Q. Those means existed prior to Edison's work upon the incandescent lamp, did they not?

A. They did.

59 x-Q. Were not the vacua obtained by Crookes in his radiometers prior to 1878 much higher than the vacua of many of the commercial incandescent lamps of the present day?

A. Probably.

60 x-Q. What do you understand by a high vacuum at the present time?

A. I should call it a high vacuum if the air or other gas were reduced to, say, the one-millionth of its original density at atmospheric pressure.

61 x-Q. Supposing it were reduced only one-tenth as much, namely, to one one hundred thousandth of an atmosphere; would it still be a high vacuum?

A. In ordinary pneumatics, yes.

62 x-Q. In the pneumatics of electric lighting, how?

A. As compared with the older and earlier practice it would be a very high vacuum.

63 x-Q. What is the vacuum existing in the best barometric tubes of the present day?

A. A very difficult question to answer. It is well known that the vacuum may be made so complete that when the mercury rises it fills the upper parts of the tube, and completely adheres to it so as not to be dislodged. In other words the tube remains completely full. Such a tube may be restored to usefulness by the introduction of an exceedingly small bubble of air, which rises into the upper part of the tube, becomes diffused over the walls of the glass, and so prevents the injurious adhesion.

Adjourned until Friday, July 18, 1890, at 11 A. M.

New York, July 18, 1890.

Met pursuant to adjournment.

Present—R. N. Dyer, of counsel for complainant; S. A. Duncan, of counsel for defendant.

Cross-examination of the witness Prof. Brackett, continued:

64 x-Q. In your last answer do you refer to the making of barometers by the Torrecellian method?

A. In general, yes; but such a vacuum as I have described would only be produced by taking very great pains to exclude as much as possible of the residual

gas. A vacuum would be a Torrecellian vacuum even if it were not carried to the extent indicated in my last answer.

65 x-Q. How high a vacuum was it possible to obtain by the Torrecellian method as the same had been improved up to 1845?

A. An exact answer would be difficult to give, in terms of atmospheric pressure. But certainly better than was ordinarily obtained by the use of air-pumps, when suitable precautions were taken to secure cleanliness of the tube and of the mercury employed, and to exclude all other substances which might absorb the air or gas, or forcibly retain it by surface attraction.

66 x-Q. You have no doubt, I presume, that King designed to create as perfect a vacuum in the carbon lamp described in his British patent of 1845, as it was possible to produce by the method which he indicates?

A. I suppose he intended to take full advantage of the method which he discloses; and yet that could not have secured a very high vacuum, since the copper wire contained in his mercury-tube unfitted it for securing the best results, inasmuch as if he had attempted to boil it, the wire would almost certainly have been destroyed by amalgamation. And it is, moreover, evident that the incandescing carbon would be very far from giving up the air which it holds by condensation among its pores, even if he had boiled the mercury in the lamp chamber. Supposing him to have done so, the air or other gas contained in the carbon would be liberated when it became incandescent, and immediately begin its destructive action, which would go on until the usefulness of the lamp would be ended.

All after the word "discloses" objected to as not called for by the question, and irrelevant and impertinent.

67 x-Q. As I gather from your testimony, and particularly your answer to 11 Q., you hold that the receiving chambers or globes of the lamps preceding the Edison lamp were made in two parts, separable

from each other, because of the assumed desirability of replacing the burner when the same should give out either owing to imperfect manufacture or an insufficient vacuum, and not because of any ignorance in the art at that time as to how a high vacuum might be maintained in a glass vessel by so sealing up the walls of the vessel that there should be no joint. Is this in substance your view of the matter?

A. I have no doubt that was one of the controlling motives and a very important one. And I have no doubt also that the necessarily large and unwieldy character of the incandescing apparatus in use made this mode of construction the most natural and most easily employed. The lamps were of necessity bulky, and accordingly heavy; and, naturally, strong and thick-walled chambers and tubes were employed to contain them, which were also best suited to the means of exhaustion then known and employed. All these reasons, I think, made it natural to proceed as the early workers did, namely, constructing the lamps so that the parts were removable by the use of separable chambers.

68 x-Q. Looking at the matter of size only, how large would be the globe of the lamp which is shown in Figure 5 of the British patent of Roberts of 1852?

A. About three inches and one-half, probably, in diameter. I estimate this from the data given in the specification, and by reference to the drawing accompanying.

69 x-Q. Please examine your deposition in the McKeesport suit and state whether the following questions and answers constitute part of the same:

> "16 Q. Please state whether or not in your opinion there is a sufficient description in the specification of the patent in suit as to the character of the fibrous burner to be used for the burner, its selection, its preparation for carbonization and its carbonization to enable others generally skilled in the art as it existed at the date of the application, namely, January 9, 1880, to produce a practically operative incandescent conductor without experiment?

A. I do not think there is enough of direction or explanation to enable one to produce such a conductor as the question names. First, as to the selection of materials, the patent is indefinite. In the specification we find the inventors to declare that they have used carbonized paper and also wood carbon. In my opinion it would not be sufficient, if paper were to be resorted to, simply to state that fact, inasmuch as papers are manufactured and are well known in a great variety of forms, having a great variety of properties. Some of them, beside the fibrous material of which they may be supposed to be chiefly composed and on which their integrity depends, are loaded with mineral and earthy matters, some of them containing more or less of chemical substances, as alum, all of which, leaving mineral residue in the part remaining after carbonization, would render it liable to fusion and so to destruction, while other papers have such great want of uniformity in the disposition of the fibres of which they are composed that the carbonaceous residue left after incineration would not be of uniform texture, but would be more or less dense at certain portions, and more or less wanting in density at others, and the result in the use of such material would be very irregular heating on the passage of the current, and probable destruction of the continuity of the conductor by a process which would be set up very similar to that which goes on between points of carbon when the arc light is produced. As respects the use of wood for the same purpose, a very similar line of remark is applicable. Out of the great variety of woods known to us very few will furnish a material which, on carbonization, would be applicable to this purpose, the reason being very much the same as has been assigned for the failure in case paper were used. More in detail: In the woods with which we are familiar in temperate climates, the "distribution of woody matter in any given mass of wood is very irregular, and the relative amount of real wood present in a given bulk is not infrequently very inconsiderable when compared with the bulk. It is noticeable in the wood from the conifers, which is made up mostly of wood disposed in cells very large as compared with the air spaces between them. In most of the exogenous woods the disposition of the fibres of the wood is such that no continuous small rod could be cut from it such that every cross section of it would represent the same amount of woody material as every other. This results from the fact that in the structure of such wood, besides fibres which are more or less parallel, there are others present which cross these, and so turning the fibres aside from their straight and regular course would render it certain that in attempting to cut from such wood a regular form some of the fibres would be cut across, the result being irregularity in the distribution of the matter in the finished product, and when an electric current is transmitted through such material those portions in which the carbon residue is least abundant in cross section would be most intensely heated and the process technically known as "arcing" set up, by which the conductor would be destroyed. It seems to me, therefore, that one setting himself to construct a lamp in accordance with the patent, supposing that such a lamp could be successfully made, would find in addition to the task set before him in the patent a full field of experimentation into which he must enter and make trial with various papers or woods before he could hope for success. As to the process involved in the reduction of the raw material to the form of carbon suitable for this purpose, the patent gives no sufficient disclosure. For these reasons I think not enough is disclosed to enable one skilled in the art to make a practically operative conductor.

17 Q. In making a conductor from wood carbon

"is it, in your opinion, essential to operativeness that the material should be cut from the wood in one way rather than in another, and if so, do you find anything in the specification of the patent in suit to indicate how this is to be done?

A. In my opinion it is of vital importance that the material should be cut from the wood, supposing a proper one to be selected, so as to have the form or extended length of the conductor taken from the wood along and parallel with its fibrous structure rather than cut across the grain, for only in the former method could we hope to secure sufficient uniformity of material or homogeneousness of structure in the carbonized residue. There is nothing whatever mentioned in the patent with respect to the necessity of this or any direction given as to the mode of carrying it out.

18 Q. How large a proportion of vegetable growths, even if the material were prepared for carbonization and carbonized with the advanced skill of the present time, would, in your opinion, be at all suited for manufacture of incandescent lamp carbons, or would make a lamp which would be practically operative?

A. In my opinion only an exceedingly small fraction of the whole number of growths known to us would fulfill this condition, and it may not, perhaps, be amiss to give my reason. If we examine the class of grasses, it will be found that the structure furnished by the stems or the leaves, or indeed, by any part of such grasses, does not possess sufficient homogeneousness of structure and uniformity of density in material to fulfill the conditions required. When the silicious outer covering of the straw is removed we come upon a structure which varies in density in such a way that in my opinion it would be almost, if not wholly, impossible to shape conductors from them possessing a requisite uniformity, and if we turn to the exogenous woods the same remark is true in a higher degree perhaps. The separate annular "layers of wood have not uniformity of density throughout their entire extent, but on the contrary it varies somewhat with the advance of the season during which it is deposited, and between the annular layers or at that portion which lies between the central parts and the contiguous annular layers the wood is very open and spongy. Moreover, the wood is generally traversed in the direction of its length with cellular structure, giving to it such a character that the residue after carbonization would, in my opinion, be wholly wanting in the characteristics requisite for such a conductor, and I believe it has been found by experiment that such woods are quite unsuited for the purpose generally. It is only in that small class, and only comparatively few members of that, even, that present the pith, the cells and the whole structure bundled together in parallel distribution, known as endogenous plants, that I should expect to find success in carrying out the invention. When I say this I do not mean that such knowledge was generally in the possession of scientific men at the time of the application of this patent, but that it has been subsequently discovered. Answering the question specifically, then, I say only a very small number of materials indicated in the question would be found suited.

19 Q. Did there, in your opinion, exist in the general knowledge of the art prior to January 9, 1880, a sufficient knowledge of the conditions relative to the selection of the material and its preparation for the purpose of making burners for incandescent lamps to make the statement contained in the patent in suit in regard to the material and its preparations sufficiently definite to enable persons skilled in the art without further experiment to produce a practically operative conductor or burner for incandescent lamps?

A. I do not think there did."

Also please state whether the patent referred to in

16 Q. of that deposition was the Sawyer & Man patent No. 317,676, and whether you still maintain the views which you expressed in the said answers?

> Question objected to as immaterial, incompetent and irrelevant.

A. I have examined the printed record, and I have no doubt it is correct. The patent referred to in 16 Q. is No. 317,676 of Sawyer & Man. And I have seen no reason to change my opinions given in those answers.

70 x-Q. In your direct examination you explained how fluorescent glass operates under some circumstances to increase the light which is developed by the passage of electric current through a Geissler tube. Is this action of fluorescent glass peculiar to the light which is developed in a Geissler tube?

A. It is not. Fluorescent bodies can act in substantially the same way under the influence of solar radiations which are too short wave-lengths to be visible. And this property is frequently made available in the telescopes of spectroscopes, in order to render visible portions of the solar spectrum which otherwise could not be seen.

71 x-Q. Does it have any such effect in connection with the light of a voltaic arc or incandescent electric lamp?

A. It does.

72 x-Q. Are the authorities all agreed that air is a perfect insulator?

A. There is substantial agreement among all recent authorities, I believe, in this respect, though it is quite possible expressions may be found in the literature of the subject which, taken by themselves, could lead to the inference that the gases, including air, are very imperfect conductors. Since the work of Sir Wm. Thompson and Clerk Maxwell there is, I think, no room for doubt, however, that the gases are perfect insulators.

Adjourned for lunch.

Resumed.

73 x-Q. Are you not one of the authors of a text-book on physics published in a revised edition in the year 1888, and designed for use in colleges and universities, and is not the following statement contained in said publication (5th Edition) on pp. 246–7 :

> "Bodies are divided according as they can be classed with the metals, damp linen, or silk, as *good conductors*, *poor conductors*, and *insulators*. The distinction is one of degree. All conductors offer some opposition to the transfer of electrification, and no body is a perfect insulator?"

A. Yes.

Re-direct Examination by Mr. Dyer:

74 Re-d-Q. Is it to be inferred from the matter quoted from your book on physics that the electrical discharge which takes place in the gas contained by a Geissler tube is the same in kind as and only differs in degree from the electrical conduction which occurs in an electrical incandescent lamp?

A. By no means, as will appear by comparing the paragraph containing the quotation with section 239 (p. 350 *et seq*) of the same book. In this section and the following, the phenomena of electrical discharge in rarefied gases is set forth.

75 Re-d-Q. In answer to 30 x-Q., you state that one of the purposes of the tube shown in the Edison Patent No. 237,732 is to exhaust the lamp chamber. Please examine the patent, and state if you are correct in this respect, and in what respect, if at all, you desire to change the conclusion reached by you in answers 30 and 31.

A. In the answers referred to I inadvertently assumed that one use of the mercury columns of the lamp was to produce the vacuum within the lamp chamber. This, however, is not the case, for they act, as respects the vacuum of that chamber, only to preserve it by suitably sealing it; and at the same time, they serve "as parts of the circuit through the incandescent conductor." As respects the point in the questions, however, this fact does not alter the case at all as stated in my answers, for the size of the mercury columns is made as shown in the drawing in order that they may have sufficient conducting capacity to prevent overheating by the current.

76 Re-d-Q. In 35 x-Q., a portion of your deposition in the McKeesport case is introduced; I call your attention to answer 85 of the introduced matter. Would the use of a platinum wire for the lower connection of the King lamp and the sealing up of the glass chamber above the mercury column be a serviceable and useful construction for the King lamp, and one which would fulfill the purposes of the King construction?

A. In my opinion it would not, for it would defeat one of the objects which I think was intended in that construction, namely, the possibility of removal of the incandescing support when the carbon which it carries is destroyed. This construction would render a somewhat expensive apparatus entirely useless after a brief period of activity, and so would make such a lamp altogether an impracticable one.

77 Re-d-Q. In 53 x-Q., your attention is called to the opening statement in Section 140 of Maxwell's book as to the imperfect state of the theory of the electric properties of gases. Do you understand that that statement is intended to qualify to any extent the statement made further on in the same section, which you have quoted, showing that air is an insulator?

A. I do not. The quotation which I made refers to a matter of fact, and has no reference whatever to any theory, and consequently stands by itself.

C. F. Brackett.

Adjourned until Monday July 21, 1890, at 11 A. M.

NEW YORK, July 21, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

CHARLES L. CLARKE, a witness produced on behalf of the complainant, having been duly sworn, testifies in answer to questions by Mr. Dyer, as follows:

1 Q. What is your name, age, residence and occupation?

A. Charles L. Clarke. I am 37 years of age and upwards; reside in East Orange, New Jersey, and am by profession a consulting engineer and patent expert.

2 Q. What has been your training and experience as an engineer, especially with reference to electricity and electric lighting, and what experience have you had in the comparison and analysis of patents for inventions?

A. For the past nineteen years (with the exception of four years spent in obtaining a technical education) I have been an engineer. At first my experience was confined to civil engineering, and included various branches of surveying and engineering construction, more particularly of the class connected with the building of railroads. My experience in electricity and its application began in the winter of 1880, when I entered Mr. Edison's laboratory as an assistant. In the winter of 1881 I was appointed first assistant engineer and acting-chief of the Edison Electric Light Company of New York, and held this position until February 1, 1884, when I left the company. From February, 1884, until the summer of 1887 I was connected with the Telemeter Company of New York, a corporation organized to exploit invention of my own for transmitting and recording temperature, pressure, etc., at a distance, by means of devices analogous to electrical signalling apparatus for fire-alarm telegraphs. While associated with this corporation I took out several letters patent. From 1887 to September, 1889, I was employed by the Gibson Electric Company of New York (manufacturers of storage batteries or electrical accumulators) as engineer and electrical expert. As engineer of the Edison Company, my duties under Mr. Edison's directions had to do with the practical application of electricity to electric lighting. I have had an extensive experience in the general subject and its details, both in the preparation of plans of large central stations and systems of electric lighting, and in the supervision of their construction. Included in the details were the construction of dynamo-electric machines, the consideration of general systems of conductors for supplying electricity to the lamps, and the determination of the proper sizes of the conductors for such systems. In the three years during which I was connected with the Telemeter Company, my electrical experience was similar to that obtained by an electrician of a telegraph company. The prosecution of the applications for patents upon my own inventions has made it necessary for me to compare and analyze patents for inventions to a considerable extent. My connection with the Gibson Company was, electrically, a repetition on a smaller scale of my experience in the Edison Company. I was, however, constantly called upon in the company's interests to consider the novelty and scope of letters patent, and during this time I performed similar service for outside parties.

3 Q. Do you agree with Professor Cross in the opinion expressed by him, in answer to 63d question, that the problem of the "subdivision of the electric light" related only to dividing the arc light?

Objected to as indefinite and as calculated by reason of its indefiniteness to embrace matters not testified about by Prof. Cross in answer to Q. 63 of his deposition, as well as matters not properly of the nature of rebuttal—defendant's counsel here making note of the fact that in the answer referred to Prof. Cross was considering only certain utterances of Mr. Preece and Mr. Schwendler.

A. I do not agree with the opinion expressed by

Professor Cross. The literature upon the subject I think contains abundant evidence of the fact that the problem related also to incandescent lights, and that "subdivision" was attempted by means of incandescent lamps for many years prior to 1879. While some considered the possibility of its solution by means of arc lights and others by means of incandescent lights, I do not understand that the general conception of the meaning of the term "subdivision of the electric light" (likewise called "subdivision"; "dividing the current"; "distribution of the light"; etc;) consisted in the idea of dividing one large arc light into several smaller arc lights, which were to be located at desired points in the circuit just as one would divide and distribute a block of matter; but that it is related to the production of any kind of electric lamps, having an illuminating power about equal to a common gas jet and adapted to like purposes, which should possess such characteristics as would make it practicable for one generator to operate a considerable number of them located at reasonable distances from it; and which, at the same time, should be economical, durable and cheap enough to make them commercially useful, and so simple and reliable that they could be placed in the hands of the public to manipulate.

4 Q. Please give brief references to the authorities in the literature of the subject upon which you base the opinion expressed in your last answer?

> Objected to as introducing new matter not in rebuttal.

A. One of the earliest articles in which subdivision is mentioned, communicated to the French Academy of Sciences on February 27th, 1858, relates to the *platinum incandescent lamp* of M. de Changy. The following extracts from this article are taken from Higg's translation of Chap. XII. of the first edition of Fontaine's work entitled "Eclairage a l'Electricite," published in 1877:

> "I hasten to announce to the Academy the important discovery of the dividing of an electric current for lighting purposes. This current from a single source traverses as many wires as may be desired, and gives a series of lights ranging from a night lamp to a lighthouse lamp."
>
> "M. de Changy, who is a chemist, mechanician, and physicist, is thoroughly conversant with the latest discoveries, and has just solved the problem of dividing the electric light."

Chap. XI. of Higg's translation of Fontaine's work contains an article by M. Wild on the Lodygnine *incandescent carbon lamp* read before the Academy of Sciences at St. Petersburg in 1874. The last paragraph reads as follows:

> "It is not within the province of the Academy of Sciences to give judgment on the technical and other difficulties which will present themselves in the extended application of M. Lodyguine's invention, nor, on the other hand, upon the numerous practical advantages of this mode of lighting above all others; it will suffice to the Academy to state that, thanks to this invention, there is resolved in the simplest possible manner the great problem of subdivision of the electric light, and of rendering it constant, in order to recognize M. Lodyguine as worthy, in consideration of the numerous applications of his invention, to obtain the Lomonossow prize."

The preface of the same work contains the following reference to subdivision by means of incandescent lamps:

> "Three years ago much was said about a new system of electric lighting, the invention of a Russian professor, which consisted in causing the incandescence of a small rod of carbon. It was for some time believed that by the aid of this invention the light could be in some way indefinitely divided, and introduced everywhere for nearly nothing."

The following extracts are from Chap. XII. of the same work:

> "The remarkable effects of the voltaic arc were no sooner foreseen than the idea arose of dividing the electric light, and even before the existence of a good regulator for a single light, King took out a patent for a lamp on the divisible system."
> "The merits of the systems of King in 1845, and of Jablochkoff in 1875, are of an exceptional character, and it would be a matter of difficulty to decide which of them approaches nearest to the true solution of the difficult problem of dividing the electric light."

The King lamp was an incandescent lamp and Jablochkoff's an arc lamp:

> "It must not, however, be thought that in face of these obstacles the idea of replacing gas by electricity will have to be entirely renounced, for science is far from having attained the last of its conquests by means of this mysterious fluid, which has already annihilated distance, and may also be said to have suppressed night; but despite the remarkable labors of M. Jablochkoff and the no less remarkable initiative of M. Denayrouse, there exists at the present time no sufficiently practical system of so dividing the light as to render it generally available for the purposes for which gas is used."

The last paragraph, I think, shows that the problem of subdivision related to the production of a lamp having the advantages possessed by a gas jet.

Extract from Chap. X. of Higg's own book, published in 1879, and entitled "The Electric Light in its Practical Application."

> "The nearest approaches to the practical subdivision of the electric light have been made by Brush, Jablochkoff and Edison."

The Brush and Jablochkoff lamps were arc lamps. The Edison lamp referred to was the incandescent platinum spiral lamp.

In an article published prior to May 15, 1879, in Vol. 1, of "La Lumiere Electrique," Du Moncel, in speaking of the properties of platinum when heated to incandescence by an electric current, says:

> "This explains why the division of the light is effected with great loss, for, from each diminuition of the current arising from this division, there results a loss of light which might, under certain conditions, reach the 11th power of the ratio in which the current has become weakened."

Extracts from Prof. S. P. Thompson's lecture on "The Electric Light," published December 20, 1878, in Vol. 26 of "Engineering."

> "The problem of dividing the electric light is an old one. So far back as 1847 a patent was taken out in England for producing a light by passing the electric current through a thin rod of carbon, which it heated to redness, like those wires with which we experimented."
> "Another attempt was made in 1858, when M. Jobart announced to the French Academie that M. Changy had solved the problem of subdividing the electric light. The small lamp of M. Changy consisted of a glass globe enclosing an incandescent spiral of platinum, and small enough to go into the pocket."
> "Now, we have heard a great deal of late of Mr. Edison and his discovery of a means of indefinitely subdividing the light."
> "If we are to accept that statement (the author refers to an article published in the "Scientific American"), it consists in passing a current of electricity through a small coil of platinum wire, * * *."
> "He, therefore, obtains the light not by an electric arc but by incandescence."

"I cannot tell you what Mr. Edison's particular method of distributing the current to the spirals may be, but this I can tell you, as the result of all experience, that any system of lighting depending on incandescence will utterly fail, from an economic point of view, and will be the more uneconomical the more the light is subdivided."

The extracts quoted refer to incandescent lamps. Again he says:

"The former (referring to the electric light from an arc lamp) gives us splendid concentration of light at a distinctly cheaper rate than could be obtained by the consumption of coal gas. But the loss in subdivision is so great that for domestic purposes the use of electricity is accompanied by such an extravagant expense as not to permit of it becoming general. I do not say that the electric light will never supplant gas for domestic purposes; he would be bold who would venture to assert that anything is impossible in science; but I do say that, so far as the present state of science warrants us in pronouncing a judgment, electric lighting for domestic purposes will not pay."

In my opinion, the last paragraph quoted shows that the problem of subdivision related to the production of lamps which would have the advantages possessed by gas jets.

The following extract from Chap. XII. of Higgs' translation of Fontaine's work is to the same effect:

"There is no doubt that each of the systems proposed is capable of rendering important service in special cases, but the error that inventors have fallen into has been the claiming of too great a scope for their apparatus as leading immediately to the supplanting of gas."

The following extract from a paper on "Dynamo-Electric Apparatus," by Higgs and Brittle, read and

published in 1878, in Vol. 52 of the Trans. of the Institute of Civil Engineers, London, is to the same effect.

"It may be laid down as proved by experiment, that for lighting large spaces, not too much subdivided, the advantages are greatly in favor of the electric light; but that where numerous light-centres of small intensity are required, or where the space is much subdivided, the advantage is in favor of gas. This advantage will cease when a practical method of subdividing the electric light has been obtained."

Extracts from "Lecture upon the Electric Light" by Prof. Henry Morton, delivered before the American Gas Light Assoc. on October 17, 1878, and published in the American Gas Light Journal, January 2 and 16, February 3 and 17, 1879.

"In this connection it is curious to notice that the latest accounts from Mr. Edison show that he gets a light equal to about 48 candles (the author refers to Edison's incandescent platinum lamp) or three argand gas burners, per horse power with his new device, and with similar machines for producing the electric current and the electric arc, from 1,000 to 2,000 candles per horse power; thus showing remarkable agreement with these earlier experiments as to the loss of effect resulting from the subdivision of the light."

"It is certain that none of these lamps (referring to the prior incandescent lamps) have yet demonstrated anything like such practical success as can enable us to see that they can take the place of gas in ordinary illumination. They have of course many advantages in certain respects over the electric arc, but these are combined with compensating drawbacks on the part of economy."

"It will be noticed that here, as with all other lamps working by incandescence, there is a great loss, which increases with the subdivision." (The particular lamp referred to here is Werdermann's semi-incandescent lamp.)

"Heretofore electric lights have only been practically developed in their concentrated form, and it certainly has *not* yet been shown that, when divided there will be an enormous loss of efficiency. Gas, on the contrary, has heretofore only been practically used in its divided form, and there can be no doubt that its efficiency is capable of much increase when it is burned in a concentrated manner."

"It is here where the actual contest will come in, and the relative success of the two sources of light in each field will depend upon what it will accomplish in that field and not in some other. In other words, we must compare the divided electric lights (say Mr. Edison's, when they become visible) with ordinary burners, and the electric arc light with the lime-light, or some such concentrated form of gas burning."

The above citations from Prof. Morton's lecture, I think, show quite conclusively that subdivision related to incandescent lighting, and the production of a lamp applicable to the same purposes as a gas jet.

The following extracts from the British Parliamentary Report on "Lighting by Electricity" published in 1879, I think also point to the same conclusions.

"Mr. C. W. Siemens, D.C.L., LL.D., F.R.S., called in and examined: * * *

259. Has your attention been called to some of the more recent experiments of Mr. Edison, and to the success which he is stated to have achieved in subdividing the light, and making it applicable for rooms and dwellings, and so on, with great ease and cheapness? I have, and I think Mr. Edison can no doubt, produce by this means a very steady and possibly an agreeable light." (Edison's incandescent platinum lamp is the one under consideration.) "260. And a cheap light he claims, I believe? Dynamically speaking, I think he has to

prove his case yet. Our experience, as far as I can judge from my own, leads me to an opposite conclusion."

"Mr. Conrad W. Cooke, recalled, and further examined.

* * * * * *

388. Have you given attention to the question of obtaining light by means of incandescence, necessitating a closed circuit?

I cannot speak with any practical experience of that.

My view of it is that you would have a far greater loss. It could be done so economically, but it would probably be applicable in cases where economy was not so much of an object, and where there was some special reason for dividing it.

* * * * * *

421. Is it not desirable that it should be subdivided?

It is very desirable, for illuminating purposes, that you should distribute your lights in a great many places; but the moment you divide your current, at each point of division you lose a certain amount. In fact, you might almost compare it to changing money where you have to pay commission at each change.

422. I suppose that the fact that it cannot be subdivided is one of the difficulties in its practical use now?

That is one of the great difficulties in street illumination, and it is the insuperable difficulty at present as regards domestic illumination; but for the illumination of large halls and large areas I think that centralization is better than subdivision."

Extracts relating to subdivision by means of incandescent lamps, taken from a letter by William Trant and published Nov. 21, 1879, on the 52d page of Vol. 19 of "Nature."

"Lighting by incandescence has been studied for a long time; indeed, it has been studied much more thoroughly than any other kind of electric lighting. Thirty-three years ago a method of producing and subdividing the light was patented in England by a Mr. King."

"The principle of incandescence, although not neglected or forgotten, seems to have made but little progress until 1871, when M. Lodygnine showed an experiment in the Admiralty Dockyard, in St. Petersburg, when he divided the circuit into no less two hundred lights."

Contrary to the opinion of Prof. Cross, in his answer to Question 63, I think that it is perfectly obvious that both Preece and Schwendler, in their papers there referred to, considered the relation of incandescent lamps to the problem of subdivision. Preece, in mathematically considering the problem, assumes throughout his paper that the resistance (l) of one lamp represents the resistance of either an arc or an incandescent lamp, for he says:

"4. Now let us take the case of a battery whose electro-motive force is E and whose internal resistance is p. Let the resistance of the connecting wires be r. Let us also have a particular resistance l, which may be a wire heated to incandescence, or a lamp to be lit by the arc; then by Joule's Law (1)." (Here follows the mathematical formula on the subject).

"In the case of incandescence, if the heat be distributed over two wires instead of one, inasmuch as the mass to be heated in the one case is double that in the other, the actual temperature to which each of the wires will be heated will be only one-quarter of that obtained with one wire, and the total light emitted will be half what it was before. In the case of the arc a similar result probably takes place."

In criticizing Preece's paper, Schwendler says:

"The author believes that he has demonstrated that the division of the electric light is impossible. This it certainly is, under the conditions introduced by Mr. Preece, namely, that the resistance of each voltaic arc or each incandescent wire is maintained *constant*, but it is not fair to introduce this condition, especially as it does not at all represent the question at issue.

* * * * * *

If Mr. Preece will introduce this condition into his equations, he will find that theoretically the division of the electric light is quite possible; *i. e.*, that theoretically, however the lights be arranged the unit of light will always be produced by the same expenditure of energy. Inventors should not therefore be downhearted. On the other hand investors in gas need not hasten to get rid of their shares, for there are many questions involving practical difficulties which still remain to be solved;"

Schwendler considers that the question of subdivision relates to incandescent lighting, and he attempts to show that, theoretically, it can be accomplished.

In the light of the above quotations from the literature upon the art, I think it is obvious that the problem of subdivision of the electric light was commonly understood to relate to incandescent lighting as well as to arc lighting, and that its solution was looked for in the production of an electric lamp, having advantages possessed by a gas jet, as set forth more fully in my answer to the third question.

In this connection I might add that Prof. Morton, in an interview published in the New York Times for December 28th, 1879, stated that what is commonly meant by the phrase, "dividing the electric light," is, "the economical production of small lights by electricity."

5 Q. Please state what, prior to the filing of the application for the patent in suit, was the opinion of

scientific men as to the possibility of the accomplishment of the subdivision of the electric light?

Objected to as immaterial and introducing new matter not in rebuttal.

A. Prior to the filing of the application for the patent in suit on November 4, 1879, scientific men were almost unanimously of the opinion that subdivision of the electric light was impossible of accomplishment. While some few men of scientific eminence were optimistic in their views and thought that the future might bring success, they were all of the opinion, so far as I know, that at that date the problem yet remained to be solved.

6 Q. Please refer briefly to some of the opinions of scientific men upon this subject, of which you have knowledge; and state generally what led them to express those opinions.

Same objections.

A. The invention of the Gramme and Siemens dynamos gave to the public two simple and reliable machines capable of generating large quantities of electricity with an economy not before attained. This led to a growth in the interest taken in electric arc lighting, which increased as installations and improvements in the details progressed, so that upon the appearance of the Lodyguine incandescent carbon lamp in 1873, renewed interest was awakened in incandescent lighting, and it was at once thought by some that the problem of subdivision had been solved. Such, however, was found not to be the case. But the interest in the subject continued, and from 1873 to the time the application for the patent in suit was filed, constant effort was made to subdivide both the arc and incandescent light. Want of success led scientific men to experiment, and investigate the subject mathematically, and to publish their views. Rapid process in the installation of the electric arc light, and persistent efforts

of inventors to produce a commercial lamp which would do the work of a gas jet, caused considerable anxiety on the part of those financially interested in gas lighting. To allay their fears, certain scientific men, conscientiously believing that subdivision was impossible or that its accomplishment was very remote, felt called upon to express their opinions on the subject. The literature relating to the state of the art and the possibility of subdividing the electric light is quite voluminous. Among other things I find the following:

Extracts from Chapter XII., of Higgs translation of Fontaine's Book on Lighting by Electricity, London, 1878. (The original French edition was published in Paris, in May, 1877).

> " * * * there exists at the present time no sufficiently practical system of so dividing the light as to render it generally available for the purposes for which gas is used. Each decade gives birth to a new idea, the importance of which is exaggerated by rumor, until, after a few unsuccessful trials, public interest abates, and nothing more is heard of the matter."
>
> "By the term 'divisibility of the electric light,' we do not mean the production of several intense lights by means of one machine or battery, but simply the maintaining of a few small luminous centres, each equal to 1 to 15 Carcel burners. It has been proved beyond doubt that several lamps can be kept in action by one magneto-electric machine, but the question is whether the first cost and maintenance of such apparatus is not greater than that of a series of small machines each in circuit with a lamp. We have always favored the latter method of lighting, although the other plan has received a large share of our attention, and there is a likelihood that M. Gramme will still have the honor of making it a practical success. At present, however, the means proposed for attaining this divisibility of the light have been practically without success."

"We will now glance at the various systems devised for solving this problem. It has been shown that the invention of King, re-invented by M. Lodyguine, and improved by M. Konn, was better suited to a single light than to a divisible system."

(These were incandescent lamps.)

"Last year (1876) when traveling through the principal towns of the United States we endeavored to discover what progress had been made in America in the matter of electric lighting, but we were unable to see anything of a practical nature."

"Many physicists had been experimenting with a view to the division of the light, but none of them were in a position to show us an apparatus worthy of even being mentioned."

"By this arrangement Mr. Jablochkoff hoped to produce fifty lights with a single magneto-electric machine. The aspirations of MM. King, Lodyguine, Konn, Kosloff and de Changy were of a like nature, and we wish M. Jablochkoff better success than his predecessors obtained."

The second edition of Fontaine's work was published in Paris in 1879. It seems to me a significant fact that in this edition the author omits the chapter on "Divisibility of the Electric Light," which appeared in the first edition of 1877.

Extracts from the Preface of the second edition of Fontaine.

"For lighting private dwellings gas offers the most desirable, the most convenient and the most economical solution. Electricity will, indeed, be able here and there to penetrate into some large drawing rooms or into some costly mansions, but this will be an exception so rare that it is not necessary to take account of it."

"The field for exploiting this new industry is immense, but it certainly does not represent the one-hundredth part of the general lighting, and it may be predicted, without the least exaggeration, that general lighting will soon increase."

"Electricians may, therefore, pursue their researches, because their labors will receive, without any doubt, their just reward; on the other hand, the managers of the gas companies can remain tranquil, their rights are most certainly sheltered from a fall. At least such is the humble opinion of the author."

The only mention of subdivision in the preface is as follows:

"Gas possesses, as a luminous agent, some remarkable properties; it produces a very uniform lighting, resulting from its division into a large number of low-power lights."

"Its inconveniences" (the author is speaking of arc lights) "which are especially the consequence of its recent introduction, and which the experience of some years will certainly partly overcome, can be summed up as follows: it loses much of its intensity when it is divided into small foci, which renders it difficult of application to small apartments."

Extracts from Chap. XIII. of the same work, entitled "Lighting by Incandescence."

"While, thanks to the efforts of MM. Gramme and Jablochkoff, lighting by the voltaic arc has received considerable development, lighting by incandescence has likewise made rapid progress, which has even recently caused a great disturbance in the investments of the gas industry, although it has not yet been developed into anything practical. An American journal, having stated that Mr. Edison was going to light an entire section of New York by electricity, a large number of the shareholders of gas companies, of the Old World as well as of the New World, hastened to sell their holdings, and threw the market for these excellent investments into a veritable panic.

To-day tranquility is restored, the statement of the journal in question is justly considered as a hoax, and shares have returned to their old value. But the market remains very sensitive, and we would not be surprised to soon see it again agitated by reports also devoid of foundation.

The truth is that the celebrated inventor of the phonograph has only re-edited a platinum wire lamp, which has already been experimented with, perfected, and finally confessed to be unsuited to industrial use by several electricians of great merit.

"We will rapidly examine the devices which have been proposed for producing the electric light by the use of a badly conducting body, raised, by the current, to a temperature near the point of fusion.

These devices can be divided into three classes: 1st, metallic spiral lamps; 2d, lamps with carbons held in clamps or sockets (*charbons encastrés*); 3d, semi-incandescent lamps (*lampes à contact imparfait*). We will mention particularly in the 1st class the lamps of de Moleyns, Petrie, de Changy and Edison; in the 2d class the lamps of King, Lodyguine, Konn, Bouliguine and Fontaine, and in the 3d class, the lamps of Varley, Reynier, Werdermann and Ducretal."

"*Edison's lamp.* The experiments in lighting by incandescence of platinum continued after 1858, and several electricians attempted to render it practical; but none of them succeeded in advancing a single step in the matter. It was even believed that it had been abandoned forever, when this famous American note arose which attributed to Mr. Edison the honor of having solved completely the problem of the divisibility of the electric light by means of platinum spirals."

Then follows a short account of Edison's French

patent for a platinum spiral lamp, and continues as follows:

"But all this does not constitute an invention susceptible of immediate applications and, still more so, to influence a market as important as that of gas investments.

2d. *Lamps with carbons held in clamps or sockets.*

Lighting with carbons held in clamps or sockets has been studied for a very long time; but its usual application has met with such great difficulties that to-day they are still to be considered as in a purely scientific stage, although to-day a certain number of devices exist which work pretty well."

"Of all the physicists who have occupied themselves with incandescence, M. de Changy has made the best spiral lamp, M. Konn the best lamp with carbons held in clamps or sockets, and M. Reynier the best semi-incandescent lamp. The last would, without doubt, arrive at a practical solution of the problem of lighting by small electrical foci did it not present some difficulties almost insurmountable."

"In the actual state of affairs, with the electrical generators in use and the lamps proposed for utilizing the electricity, we do not believe that lighting generally by electricity can be made to succeed.

Circumstances may present themselves where its application will be interesting and even useful, but to develop them, it is necessary to invent a gas engine of moderate price or thermo-electric batteries must become really practical. In the meantime we can recommend incandescent lamps, particularly that of M. Reynier, in laboratories and in factories which already have electrical lamps for powerful foci, and which can, without inconvenience, interpolate one or several semi-incandescent lamps in the circuit."

From the above quotations from the two first editions of Fontaine's book I think it is apparent that Fontaine, who had inquired into the state of the art very fully, was of the opinion that subdivision had not then been accomplished, and that it was to his mind impossible. It is to be noted that, at the end of the second edition, he recommends the use of a semi-incandescent lamp to those who want a light of lesser power than the arc light. The semi-incandescent principle was at one time a favorite mode of attempting the subdivision of the light, but, as far as I know, the use of such lamps and all efforts to succeed in this direction were abandoned about the year 1881.

Extract from Chap. X of Higgs' own work, published in 1879, entitled "The Electric Light in its Practical Application":

> "'The division of the electric light' is a term, the true rendering of which should be the 'division of the electric current,' to produce numerous small light centres instead of one or more powerful lights. Much nonsense has been talked in relation to this subject. Some inventors have claimed the power to 'indefinitely divide' the electric current, not knowing or forgetting that such a statement is incompatible with the well-known law of conservation of energy.
>
> Whether the electric current be utilized in the production of light, either by means of the voltaic arc or of incandescence, the production of a certain amount of light depends upon the amount of current passing, not directly, but in such a proportion that offers speedy limit to the number of lights to be obtained."

Higgs apparently was of the opinion that subdivision was altogether impossible either by arc or incandescent lamps.

Prof. Morton, in his "Lecture upon the Electric Light," to which I have already referred, after mentioning Farmer's platinum lamp, which was exhibited in 1859, says:

> "It is true that nineteen years have not sufficed to render this admirable arrangement successful in practice, but what is that to the prophetic mind, which, foreseeing what is to happen in the 'near future,' naturally overleaps distinctions between past and future, theory and practice. For us, however, who only know the past and present, it may be well to look a little closer at the means actually used, and the results obtained in these and other experiments."
>
> "True, this achievement (the author refers to a regulator to prevent the fusion of the wire) was claimed for M. de Changy, and seems to be implied in Mr. Farmer's description, but somehow, as with the famous perpetual motion machine, 'the little screw which makes all go' does not appear to have been forthcoming in either case; and in this present year of 1878, we still look to the 'future,' 'near' or remote, for the 'practical success' so confidently announced nineteen or twenty years ago."
>
> "It is certain that none of these lamps (referring to incandescent lamps) have yet demonstrated anything like such practical success as can enable us to see that they can take the place of gas in ordinary illumination.
>
> They have, of course, many advantages in certain respects over the electric arc, but these are combined with compensating drawbacks on the part of economy; and it is only by turning our eye to the yet *unrevealed possibilities of the future* that we are able to see the electric light as *a successful substitute for gas and other methods of illumination.*"

As I understand it, Prof. Morton held the opinion that no lamps which could take the place of gas in ordinary lighting, had yet been devised, that the electric light had only been employed practically in the concentrated and powerful arc, and that the future would possibly see the accomplishment of its subdivision.

Prof. Morton still later, in his report dated Nov. 20, 1879, to the Chairman of the Lighthouse Board, states that no practical incandescent lamp had yet been devised. This was after the date of application for the patent in suit but before the public had knowledge of the invention contained therein. In this report Prof. Morton, among other things, says:

> "Notwithstanding this very promising beginning, however, little or no progress seems to have been made in this method of lighting for the twenty years intervening between the dates above given and the present time, for we certainly have no system of electric lighting by incandescence superior to that above described, nor has this older one or any of its newer arrivals come into any general use."
>
> "Though none of them have proved practically useful as yet, nevertheless some notice of methods of lighting by incandescence should be here given historically for future reference * * *."

I think that the following quotation from Prof. S. P. Thompson's lecture on "The Electric Light," previously given in my answer to the second question, shows that the author deemed subdivision with incandescent lamps to be impossible. He was not prepared to say that the problem itself could not be solved, but acknowledges that the state of the art did not indicate any direction in which to proceed.

Professor Thompson says:

> "I cannot tell you what Mr. Edison's particular method of distributing the current to the (platinum) spirals may be, but this I can tell you, as the result of all experience, that any system of lighting depending on incandescence will utterly fail from an economic point of view and will be more uneconomical the more the light is subdivided."

> "The former (referring to the electric light from an arc lamp) gives us a splendid concentration of light at a distinctly cheaper rate than could be obtained by the consumption of coal gas. But the loss by subdivision is so great that for domestic purposes the use of electricity is accompanied by such an extravagant expense as not to permit of its becoming general. I do not say that the electric light will never supplant gas for domestic purposes; he would be bold who would venture to assert that anything is impossible in science; but I do say that, so far as the present state of science warrants us in pronouncing a judgment, electric lighting for domestic purposes will not pay."

After investigating the question of subdivision, both by arc and incandescent lamps, Preece, in his paper already referred to, says:

> "It is this partial success in multiplying the light that has led so many sanguine experimenters to anticipate the ultimate possibility of its extensive subdivision, a possibility which this demonstration shows to be hopeless, and which experiment has proved to be fallacious."

In a later paper, in which both arc and incandescent lamps are considered, Preece says:

> "Hence, the subdivision of the light is an absolute *ignis fatuus.*"
>
> See the Tel. Jour. & Elect. Rev., Vol. VII., Feb. 15, '79.

The following extracts from the editorial columns of two English technical journals of the best repute will serve as an indication of the opinions from that direction:

> "It (referring to Edison's platinum lamp) will be severely handicapped against all electric arc systems by the physical drawback common to all incandescent systems, namely, that for each addi-

tion to the number of lights in circuit an enormous reduction is made in the intensity of the light produced."

See "Engineering" for February 21, 1879.

"Before the electric light can be subdivided with facility and economy, the operation of some new law must be discovered, and that we hold to be extremely improbable."

See "Engineer" for January 10, 1879.

"If the current can be successfully divided among dozens of such lamps (referring to Edison's platinum lamps), then may gas-makers quake, but nothing of the kind can be done."

See "Engineer" for February 14, 1879.

Du Moncel concludes a paper entitled "Consideration on Public Lighting by Electric Processes," with these words:

"We, therefore, believe that, if the solution of the problem of electric lighting is not yet complete, there has been made, in recent times, a real progress which, being wisely studied, might lead to wholly satisfactory results."

See "La Lumiere Electriqua," Vol. 1, No. 1; published prior to May 15, 1879.

Mr. Conrad W. Cooke testified before the Parliamentary Committee as follows:

"422. I suppose that the fact that it cannot be subdivided is one of the practical difficulties in its use now? That is one of the great difficulties in street illumination; and it is the insuperable difficulty at present as regards domestic illumination; but for the illumination of large halls and large areas I think that centralization is better than subdivision."

"425. Dr. Siemens, in referring to Mr. Edison, who is credited with having recently invented a machine for subdividing the light, expressed

some doubt on the subject, and stated that he thought it was not as promising as the reports indicated; do you know anything about that? We really know very little at all about it. A few newspaper paragraphs have appeared on the subject, and I have been very much interested, as everybody has. His nephew told me himself, that he has seen, I think, over 200 lights in one circuit. I must say I should like to see it myself, and that is all I can say."

Mr. Preece said before the same committee:

"515. Then, according to your view, the electric light is really economical when it is used for giving central lights, but not when it is used in a subdivided form? It is only economical when one machine is used to produce a single light.

516. Any departure from that means waste, economically speaking? Certainly."

Sir William Thomson testified in part as follows:

"1780. But there is nothing in the mathematical discussion of the question that should render that reduction necessarily by the square or the cubes? No; it is quite possible that a plan of using electric energy for light might be found and may yet be found, in which ten feebler lights will give a sum of light equal to that obtainable by the same energy in one concentrated light."

See Parliamentary Report on "Lighting by Electricity," published in 1879.

In his letter to "Nature" on the "Divisibility of the Electric Light," already referred to, William Trant concludes with this statement:

"It will be seen then from what has been above stated, that the production and the divisibility of the light by incandescence is a very wasteful process, so wasteful, indeed, as to render its practical application impossible for general lighting. If, therefore, all Mr. Edison has to announce to the world is that he has succeeded in dividing an incandescent light (the author has Edison's platinum wire lamp in mind), and the announcement that such is so is made on authority, his discovery amounts to very little. Both the light and its divisibility were discovered long ago. It will easily be seen that it is not in that direction that any great practical results can be obtained. The voltaic arc supplies the only divisible light of any utility and economy, and it is in its development that any real progress must be looked for."

A work written by Alex. Bernstein, entitled "Die Electrische Beleuchtung" (Electric Lighting) was published in Berlin in 1880. The preface is dated November, 1879. The author at that time evidently could not have had knowledge of the invention contained in the patent in suit. Bernstein describes the known forms of arc and semi-incandescent lamps, and the incandescent lamps of King and Lodyguine and also Edison's platinum lamp.

His opinion of the possibility of subdivision is given in the following passages translated from Chap. III. of his work:

"For these reasons we arrive at the result that a limit to the subdivision of the light is imposed by the known forms of electrical carbon lights, which cannot be overstepped without the excessive cost of operation appearing as a substantial loss."

"If we succeed in overcoming the objections, the electric light of this type has a very important future in those parts of the earth, in which motive power is abundantly and cheaply at hand.

At present we must be content to make use of electric lighting by means of an intense light unless the properties of the electric light, which we have considered in detail, yield additional advantages under other conditions."

I think that the above extracts from the literature of the art bear testimony to the substantial correctness of my answer to the fifth question, concerning the opinion of scientific men as the possibility of subdivision.

7 Q. What were the reasons that led scientific men to reach the conclusion that the subdivision of the electric light was an impossibility, and were those reasons well founded in fact?

Objected to as containing a false assumption, and one that is refuted by the quotations embodied in the last answer of the witness and in the context of the passages quoted, as fully appears by reference to the original documents.

Complainant's counsel objects to the statement by defendant's counsel as not being true in fact and as not being proper evidence of the facts stated.

A. Aside from the reasons which related to the details of lamp construction and durability of the burner, theoretical considerations and experiments led scientific men generally to believe that the diminution in the amount of light obtained, when even a very few burners were in circuit, would be so great as to make subdivision commercially impossible. The incandescent electric light systems in use to-day are a practical proof of the fact that the reasons which led to this conclusion were not well founded.

8 Q. Please refer to the literature on the subject, and cite instances where subdivision was pronounced impossible for the reason given in your last answer?

Objected to as introducing new matter not in rebuttal.

A. Fontaine ascertained experimentally the effect of adding incandescent lamps to a circuit. He says:

"In order to realize the actual value of the system of lighting by incandescence, we have made a series of experiments with several of Konn's lamps and a Bunsen battery of 48 elements, of 0.20 metre height. * * * The following results represent the mean of more than twenty series of experiments."

Here follows a tabulated result of his experiments. With the battery arranged in different ways, he found that

when 1 lamp in circuit gave a light of 4 to 5 burners,
 5 lamps *in series* were each reddish white;
when 1 lamp in circuit gave a light of 11 to 12 burners,
 5 lamps *in series* were each cherry-red;
when 1 lamp in circuit gave a light of 40 burners,
 5 lamps *in series* were each dull red;
when 1 lamp in circuit gave a light of $6\frac{1}{4}$ to 7 burners,
 5 lamps *in series* gave a *total light* of $2\frac{1}{4}$ burners;
when 1 lamp in circuit gave a light of 9 burners,
 3 lamps in *multiple-arc* gave a *total light* of 1 burner;
when 1 lamp in circuit gave a light of 54 burners,
 5 lamps *in multiple arc* gave a *total light* of $\frac{1}{4}$ burner;
when 1 lamp in circuit gave a light of 65 burners,
 5 lamps *in multiple-arc* gave a *total light* of $2\frac{1}{4}$ burners;
when 1 lamp in circuit gave a light of 8 burners,
 3 lamps *in multiple-arc* gave a *total light* of $\frac{3}{4}$ burner.

The results of Fontaine's experiments as outlined above show that the addition of a very few lamps to the circuit, either in series or in multiple-arc, was accompanied by an enormous loss of light. In fact, when the battery was so arranged that a single lamp in circuit gave a light of from 40 to 65 burners, the addition of four lamps resulted in the production of practically no light.

Fontaine concluded that—

"From what precedes, it appears to result that King and Lodyguine's system is much more favorable to large foci than to the divisibility of the electric light."

See Chapter XI. of Higg's Translation of Fontaine's Work on "Electric Lighting."

The fallacy underlying Fontaine's experiments in attempting subdivision, which fallacy appears to have been quite generally adopted by scientific men after the date of these experiments, was in assuming that the smaller lights were to be obtained without change in the construction of existing lamps, by delivering a smaller current to each lamp, thus reducing the temperature of the burner at each lamp and the amount of light emitted by it. But, since the heat developed in the burner decreases in a much greater ratio than the decrease in the current (as the square), and since the light decreases much more rapidly than the heat, Fontaine found that the smaller lights were obtained only by an enormous loss of energy, which (no other method of subdivision being thought feasible) enforced the conclusion that subdivision was an impossibility.

In his "Lecture upon the Electric Light" already referred to, Professor Morton says, in regard to lamps similar to the Konn incandescent carbon lamp, that

"The third characteristic is the manner in which the light-producing power of the current diminishes as it is distributed between a number of lamps. Thus, the current from a given battery, acting on one lamp, produced a light between 4 and 5 burners; on two lamps, a light of $1\frac{1}{2}$ burners each; on three lamps, one-third to two-thirds of a burner each. From another battery, the current on a single lamp gave a light of 11 to 12 burners; with two lamps, one-half burner each; and on three lamps, one-ninth of a burner each.

In another case a given battery with one lamp gave a light of nine burners; with two lamps, $2\frac{1}{4}$ burners; and with three lamps, one-third of a burner each. Another battery with one lamp gave a light of 65 burners; with two lamps, $7\frac{1}{2}$ burners; with three lamps, $1\frac{1}{3}$ burners; with four lamps, three-fourths of a burner; and with five lamps, one-half burner each."

It appears from this that Prof. Morton entertained the same fallacy as Fontaine.

In Preece's paper on "The Electric Light," to which I have already referred, the assumptions upon which the mathematical investigation in the first part of the paper were based represent the conditions which were present in the experiments made by Fontaine with the Konn lamps. Preece's conclusion from these assumptions is as follows:

"So that, *joined up either in series or in multiple arc, the heat generated in each of a number of resistances varies inversely as the square of their number.*

10. With respect to the light emitted, if the amount of heat generated represented exactly the amount of light emitted, then the above equations would indicate the effects produced by multiplying the lights or subdividing the current when a constant battery is employed. But this is not so. The light obtained is not proportional to the heat generated. Below a certain limit the production of heat is not accompanied by light at all. In the case of incandescence, if the heat be distributed over two wires instead of one, inasmuch as the mass to be heated in the one case is double that in the other, the actual temperature to which each of the wires will be heated will be only one-quarter of that obtained with one wire, and the total light emitted will be half what it was before. In the case of the arc a similar result probably takes place. * * * If, therefore, the lamps be joined up in series or in multiple arc the light emitted by each lamp will vary inversely in a greater ratio *than* the square of the number in circuit."

In the last part of the paper, Preece concludes that, when the amount of energy developed in the *entire* circuit is kept constant, the light of each lamp when they are in series will diminish as the square of the number in circuit, and as the cube of the number when they are arranged in multiple arc.

"With the Wallace-Farmer machine the limit

appears to be reached when six lamps are connected up in series. With the Gramme alternating machine and Jablochkoff candles the limit appears to be five lamps. Beyond these limits the above laws will be true. It is this partial success in multiplying the light that has led so many sanguine experimenters to anticipate the ultimate possibility of its extensive subdivision—a possibility which this demonstration shows to be hopeless, and which experiment has proved to be fallacious."

The experiments referred to by Preece are those which were made by Fontaine. It will be seen that Preece obtained mathematically the same results which Fontaine had obtained experimentally.

The following citations from various sources show the prevalency, among scientific men, of the fallacy that subdivision was necessarily accompanied with an enormous loss of light.

In his letter to "Engineering," in 1878, on the "Divisibility of the Electric Light from a Dynamical Point of View," Prof. S. P. Thompson says:

"Suppose an electric light equal in luminosity to 1,000 candles, and we want instead to divide that light into ten smaller lights. If we introduce ten equal branches, each will carry one-tenth part of the original current, and the intensity of light in each will be one one-hundredth part only of the original light or 10 candles. We shall get 10 lights of ten candles each, instead of 1 light of 1,000 candles. Clearly it might not pay to subdivide the light at this rate, though it might for particular cases pay to use the undivided current to mass the light in one bright spark of 1,000 candle brilliancy."

I find in Chap. X. of Higgs' work on "The Electric Light in its Practical Applications," the following statement:

"Suppose, then, that two lights exists of a certain power each in two circuits derived from a main circuit, and that two more lights are required to be.

added, one in each on other two circuits again derived from the main circuit; the current formerly passing in each of the circuits when only two existed will be halved by the introduction of the other lights, and, according to the law, the heating effect in each circuit will be only one-fourth of that occurring with two lights. Actually, as the lighting effect bears to the heating effect much the same relation as the heating effect does to the amount of current, the decrease of light is much greater. With a given current source the division of the electric current is, therefore, anything but 'indefinite.'"

Extract from "Engineering," for February 21, 1879:

"It (referring to Edison's platinum lamp experiments) will be severely handicapped against all electric arc systems by the physical drawback common to all incandescent systems, namely, that for each addition to the number of lights in circuit an enormous reduction is made in the intensity of the light produced."

Extract from "Engineer," for January 10, 1879:

"Electricians who were not commercially interested in any form of electric lamp or machine showed that this subdivision could only be effected at an enormous expense of light and material owing to causes which we need not stop to explain."

Extracts from the Parliamentary Report on "Electric Lighting."

"151. It would be considerably more expensive if your light was subdivided into various lights? The consumption of energy increases in a very rapid ratio, inversely as the concentration of the light. In dividing the light into two lights each will probably not give more than one-fourth of the effect.

152. Very nearly according to the squares or

more than the squares? I think it is more than the squares. Exact experiments are wanting on this subject, but so far as observations have led me to come to a conclusion, I should say that it increases in a more rapid ratio than the squares."

See testimony of C. W. Siemens.

"1779. Would you allow me to ask you about the division of the electric light into various small lights; scientifically do you agree with calculations, the results of which have been put before us, that the effect of a division must be, in some cases, to decrease the light so divided, according to the squares, or according to the cubes of the distance?

We have no scientific law of the economy of the electric light in different degrees of division and concentration; but practice and theoretical guesses seem to agree in making the economy much less when we spend the same quantity of energy, for example, in ten feebler lights than when we spent it in one strong light; when we do this we do not get nearly one-tenth part of the whole light by any of the plans hitherto in use."

See testimony of Sir William Thompson.

In an article entitled "Considerations on Public Lighting by Electric Processes," which was published in "La Lumiere Electrique" prior to May 15, 1879, Du Moncel says:

"Unfortunately, the processes of division tried hitherto have solved this problem only at the price of a great loss in the intensity of the light which could be produced at a single point."

After calling attention to Preece's statement concerning the rapid diminution in the light given out by a platinum wire with a diminution of temperature, the author states that

"This explains why the division of the light is effected with great loss, for, from each diminution of the current arising from this division, there results a loss of light which might, under certain conditions, reach the 11th power of the ratio in which the current has become weakened."

9 Q. Did the accomplishment of the problem of subdivision of the electric light, as that problem was generally understood at the date of the application for the patent in suit, require the production of an incandescent lamp of a resistance of 100 ohms hot, and upwards, and capable of use for lighting economically large areas comparable in size to those then lighted by gas?

Objected to as introducing new matter not in rebuttal. Also on the ground of immateriality, since it is immaterial what "scientific men" may have thought regarding the matter stated in the question, it being only important in this connection to know that Mr. Edison, who in his deposition has disclaimed for himself the character of a scientist, has repeatedly declared a resistance of 100 ohms hot as essential to the construction of a lamp that should aid in solving the problem of the commercial subdivision of the electric light.

Complainant's counsel objects to the statement by defendant's counsel as not warranted by the evidence and not of itself proper evidence of the facts stated.

A. I do not think so. Those who tried to solve the problem experimentally failed when only a few lamps were in circuit. Fontaine, for example, obtained practically no light at all with five lamps. Opinions based on theory, some of which have already been referred to, also led many scientists to the conclusion that the loss by subdivision would make it altogether impossible. Under these circumstances the standard of success was low, and I think that, prior to November, 1879, if quite a small number of lamps, each about

equal to a gas jet, and having the requisite durability, simplicity and cheapness, could have been run by one generator, with reasonable economy, when distributed over a limited area, it would have been deemed a satisfactory solution of the problem. To accomplish this result, lamps having a resistance of much less than 100 ohms hot could have been used.

Thompson says, in his lecture on "The Electric Light," that

"By this means M. Jablochkoff can work sixteen candles with one steam engine of 18 horse power, the lights being arranged in four series of four lamps each. We may, therefore, say that up to this point M. Jablochkoff has solved the problem of dividing the electric light."

Extract from an editorial in "Engineer," for February 14, 1879:

"With all its defects for domestic purposes, still Mr. Edison's (platinum) lamp might be used to much advantage for street lighting, and in factories or theatres, in fact, in any situation where it could be looked after by a skilled attendant. If the current can be successfully divided among dozens of such lamps, then may gas makers quake, but nothing of the kind can be done."

Extract from an article by Du Moncel, entitled "Same Reflections in regard to the New Lamp of Mr. Edison," and published in Vol. II. of "La Lumiere Electrique," January 1, 1880:

"In 1875 much noise had also been made on the subject of the lamp with incandescent carbon which, introduced in France by Mr. Kosloff, was tested for some time at Mr. Truc's, lamp maker, of Paris, and it was claimed at that time that an *Alliance* machine could illuminate 15 lamps of this kind; but, in fact, I have never been able to see more than two operating at a time."

Extract from Chap. XII. of Higgs' translation of Fontaine's work on "Electric Lighting":

> "By the term 'divisibility of the electric light' we do not mean the production of several intense lights by means of one machine or battery, but simply the maintaining of a few luminous centres, each equal to 1 to 15 Carcel burners."

Apparently subdivision would have been thought quite advanced if not wholly accomplished, when a very few lamps could be successfully operated in one circuit.

10 Q. Has the commercial development of the business of electric lighting by incandescent lamps since the date of the application for the patent in suit shown that lamps of at least 100 ohms hot resistance were required to accomplish practically the subdivision of the electric light?

Objected to as immaterial.

A. In my opinion it has not shown that lamps having as high a resistance as 100 ohms hot are at all necessary. I believe that a large number of incandescent electric light installations have been made with lamps having a resistance of considerably less than 100 ohms. I understand that the defendant company in this suit has in years past installed a considerable number of plants having lamps like "Defendant's Zig Zag Lamp," having a hot resistance of 75 ohms, and "Defendant's M. Lamp," which has a resistance hot of only 41 ohms. In my opinion lamps of this character in the absence of lamps of higher resistance would be good commercial lamps to-day, and I believe that the business of isolated lighting would not be sensibly lessened if we had no better lamps. I understand that lamps of less than 100 ohms resistance hot have been, in years past, and are now, being manufactured and sold, by the complainant company in this suit, for use on multiple arc circuits.

11 Q. I call your attention to Answers 5 to 8 of Professor Cross' deposition, in which he criticizes the statements contained in the patent in suit with respect to the prior state of the art. Do you agree with Professor Cross in his conclusions, and what are your views of the matter?

A. No; I think that Professor Cross misunderstands the statements contained in the specification of the patent in suit which relate to the prior art. As I understand it, the specification very briefly and in a general way calls attention to the important features which characterized lamps of the most promise either wholly or in part. In this sense the specification is entirely correct. I do not understand that Edison intended to say that *every* incandescent lamp made before that time possessed *all* the characteristics which are mentioned. The paragraph of the patent in suit containing the statements as to the prior art, which are criticized unfavorably by Professor Cross, is as follows:

> "Heretofore light by incandescence has been obtained from rods of carbon of one to four ohms resistance, placed in closed vessels, in which the atmospheric air has been replaced by gases that do not combine chemically with the carbon. The vessel holding the burner has been composed of glass cemented to a metallic base. The connection between the leading-wires and the carbon has been obtained by clamping the carbon to the metal. The leading-wires have always been large so that their resistance shall be many times less than the burner, and, in general, the attempts of previous persons have been to reduce the resistance of the carbon rod. The disadvantages of following this practice are that a lamp having but one to four ohms resistance cannot be worked in great numbers in multiple arc without the employment of main conductors of enormous dimensions; that, owing to the low resistance of the lamp, the leading-wires must be of large dimensions and good conductors, and a glass globe cannot be kept tight at the place where the

wires pass in and are cemented; hence the carbon is consumed because there must be almost a perfect vacuum to render the carbon stable, especially when such carbon is small in mass and high in electrical resistance. The use of a gas in the receiver at the atmospheric pressure, although not attacking the carbon, serves to destroy it in time by 'air-washing,' or the attrition produced by the rapid passage of the air over the slightly-coherent highly-heated surface of the carbon."

Edison's invention described in the patent is a lamp employing a carbon burner, and it is evident from the reading of the paragraph quoted that the statements contained in it relate to prior incandescent lamps also employing or proposing to employ carbon burners.

The statement that the carbon rods in prior lamps had a resistance of from one to four ohms is criticized as inaccurate by Prof. Cross in answer 7 of his deposition. In support of this opinion Prof. Cross refers to the patents of King and Lane-Fox and the several prior patents of Edison. All of these patents, in so far as they are intended to disprove the accuracy of the statement made in the patent in suit, describe burners made either of platinum or iridium, or a combination of carbon with other material, and do not in any way refer to burners made of carbon, to which alone the statement is intended to apply.

The statement in the patent that the carbon rods of prior lamps were placed in closed vessels in which the atmospheric air has been replaced by gases that do not combine chemically with the carbon, is criticized as inaccurate by Prof. Cross in answer to 5 Q. of his deposition, in which he refers to the King and Roberts lamps as having carbon burners enclosed in glass globes in an almost perfect vacuum. It is true that these lamps were intended to have as high a vacuum as was then obtainable, although at best it would, I think, have been very imperfect. For several years prior to the date of the patent in suit, the efforts of the art to obtain a practical carbon lamp seem to have been mainly in the direction of using chambers filled with some inert gas to protect the carbon from combustion. Lodyguine, Konn, Sawyer and Man (whose experiments were concurrent with the earlier efforts of Edison) and others worked in this direction and I think that their efforts were generally considered as giving the most promise of success. While it is true, as Prof. Cross says, that the patent makes no mention of prior carbon lamps in which a vacuum was used, I think that the omission is quite immaterial in view of the fact that the carbon lamps of most promise which were made for several years immediately prior to the date of the patent in suit, contemplated the use of chambers filled with an inert gas, and that the statement in the patent is practically a correct statement of the prior state of the art in this respect.

In answer to 6 Q. Prof. Cross takes exception to the statement made that the vessels holding the burner have been composed of glass cemented to a metallic base, in contradistinction to lamp chambers made wholly of glass. To support his views, Prof. Cross refers to two patents granted to Sawyer and Man in which glass plates or stoppers for closing the lamp chamber are described. In my opinion, these devices are in every way the equivalent of the metallic base referred to in the statement in Edison's patent. Reference is also made to three British patents of Lane-Fox. Since none of these patents describe a lamp having a burner made of carbon, Prof. Cross has evidently misunderstood the statement in the patent which refers solely to lamps having metallic bases in which only carbon burners were used. Prof. Cross further describes what he considers to be an "alternative form of the King lamp as set forth in British Patent No. 10,919 of 1845," consisting of a carbon lamp having a chamber made entirely of glass. In my opinion the King patent does not describe a carbon lamp with such a chamber, but only a lamp having a mercury cup for a base with the joint between the chamber and the cup sealed with mercury. The Roberts, Lodyguine, Konn and, to the best of my knowledge, all other carbon lamps had glass chambers which were closed with metallic bases or their equivalent. This construction of the lamps with separable parts made it easy to renew the carbon burner when broken. I do not agree with Prof. Cross in his opinion that the statement in the patent before referred to is at all inaccurate, but, on the contrary, believe it is entirely correct.

I cannot agree with Professor Cross in his answer to 5½ Q. in which he states substantially that the King and Roberts patents contemplated the use of high vacua, and says that

> "the vacuum which would have been used, if their directions were consistently followed, would have been 'almost a perfect vacuum.'"

The construction of these lamps and the art of obtaining vacua would, in my opinion, have made it impossible to obtain and preserve a vacuum in these lamps, which would be at all comparable to the almost perfect vacuum mentioned in the patent in suit; neither do I think that the inventors contemplated using or deemed such a vacuum essential.

In answer to 8 Q. Professor Cross takes exception to the statement that carbon lamps of from one to four ohms resistance require such large leading-in wires as to preclude the possibility of making a tight joint, where they pass into the chamber, and in support of his opinion refers to one form of the modern incandescent lamp made after the date of the patent in suit, having a burner much less than four ohms resistance in which the joint around the platinum leading-in wires is made perfect by fusion of the glass to the wire. The burners of these lamps, however, are enclosed in very high vacua and therefore lose very little heat by conduction and convection. If, prior to the date of the patent in suit, carbon burners of this size had been placed in chambers having low vacua or filled with inert gas, as was the case with the old lamps, the loss of heat by conduction and convection due to the gas in the globe would have very greatly reduced the temperature and illuminating power of the burner, and it is

my opinion that the increase of current requisite to raise the burner to its normal temperature and incandescence would have necessitated the use of leading-in wires so large that they could not have been securely sealed into the glass by fusion. The carbon rod burners mentioned in the earlier patents would have required large wires cemented into the lamp chamber, and so far as I know, this method was followed in all carbon lamps prior to the date of the patent in suit, excepting that of King. I therefore cannot agree with Professor Cross that it was perfectly possible to maintain a tight joint around the leading-in wires of carbon lamps having from one to four ohms resistance, but am of the opinion that, under the conditions which existed prior to the date of Edison's patent, the leading-in wires of such lamps would have been so large as to necessitate the use of cement joints which were liable to leakage as is stated in the specification.

In conclusion, I may add that the manufacture of lamps like those referred to by Prof. Cross, which have platinum leading-in wires of considerable size, did not begin until several years after the date of the patent in suit, and were only made possible by the increased skill and experience gained after that date.

12 Q. Prof. Cross, in answer to questions 30, 31 and 32, expresses the opinion that there was no invention in substituting the carbon burner of the patent in suit for the platinum burner of Edison's patent No. 227,229, and corresponding foreign patents. Please state whether you agree with Prof. Cross and give your reasons for any opinions which you may express?

A. I entirely disagree with the opinion expressed by Prof. Cross, which has apparently been formed without taking into account the fact that, prior to the date of the application for the patent in suit, incandescent carbon burners had little durability, and were believed to be necessarily subject to a very rapid disintegration and waste, resulting in their destruction in a few hours, even when they were made quite thick. I cannot agree with Prof. Cross that, if in April, 1879, he had been asked to make a carbon incandescent lamp that would be capable of the same extent of use as is claimed for the platinum lamp in Edison's United States Patent No. 227,229 (see Q. 31 of Prof. Cross' deposition), he would have known what proportions to give to the carbon burner. In his answer to Q. 31 Prof. Cross virtually states that he could have determined the proper size of the burner mathematically, "knowing (as he says, among other things), the specific resistance of carbon and its other physical properties." There was no information extant at that date relating to the specific resistance of an incandescent carbon burner or of its physical properties when enclosed in a highly exhausted air-tight chamber, and the want of such information would have precluded the possibility of mathematically determining the size of the burner which should be capable of the same extent of use as the platinum burner of the patent mentioned. In view of the fact that it was generally supposed that carbon, even when protected from the air, was rapidly destroyed when heated to incandescence, I do not think that any one would have thought it possible to substitute a carbon wire in place of the platinum wire, mentioned in U. S. Patent No. 227,229, and heat it up to incandescence without almost instantly destroying it. The possibility of preventing the rapid destruction of carbon burners was not ascertained, so far as I know, until Edison discovered, as stated in the patent in suit, that even a burner made of carbonized thread would be stable under proper conditions, *i. e.*, when enclosed in a high vacuum in an air-tight chamber. Edison appreciated the important bearing of this newly discovered property of carbon upon the question of incandescent lighting, and I am of the opinion that the construction of a lamp which made it possible to take advantage of this property of carbon, and to use a carbon burner of filamentary form, which made incandescent lighting commercially possible, was an invention of great merit and utility.

13 Q. State briefly to what extent, if at all, the opinion expressed in your last answer is sustained by the literature upon the subject?

A. Fontaine noted the rapid wasting away of the burner when incandescent. Concerning his own experiments with the Konn lamp, he says (see Chap. 11 of Higgs' Translation of Fontaine's Work):

> "The vacuum never being perfect in the receivers, the first carbon is in greater part consumed. It would appear that consequently upon the little oxygen contained in the lamp being transformed into carbonic acid and carbonic oxide, the carbon should be preserved indefinitely. But there is then produced a kind of evaporation which continues to slowly destroy the incandescent rods. This evaporation is besides clearly proved by a pulverent deposit of sublimed carbon, that we have found on the interior surface of the bells, on the several interior parts, rods, contacts, hammers, &c."

On October 17, 1878, Prof. Morton, in his "Lecture upon the Electric Light," says:

> "Various slight modifications of this lamp (Konn lamp) have been made and elaborately experimented with; but they all show the same essential characteristics. The first of these is that, as long as any oxygen remains in the vessel, the carbon rods consume rapidly, the first one generally lasting only twenty minutes. The second carbon will, however, last two hours if the light does not exceed forty burners; but even when all active gas has been removed, the carbon suffers a sort of evaporation."
>
> "Another modification of this Starr or Konn lamp is found in that which has been recently exhibited in New York as the Sawyer-Man lamp. This differs from the former apparatus in no important feature, except that the interior of the vessel is said to be filed with pure nitrogen at the ordinary pressure.
>
> The carbon rods are said not to waste away in these lamps. Without knowing anything positive

on the subject, my opinion is that this is only because they have not been subjected to strong currents, but have only been heated to the extent of yielding the light of one or two burners."

In his report to the Lighthouse Board, dated November 29, 1879, which was after the date of application and before the granting of the patent in suit, Prof. Morton again says:

"Small rods of carbons placed in exhausted tubes admitted of higher temperatures (than platinum), but were quite rapidly consumed, or rather vaporized and disintegrated."

Chap. III. of Bernstein's Book, to which I have hereinbefore referred, the preface of which is dated November, 1879, contains a statement concerning the durability of carbon burners of incandescent lamps, which I translate as follows:

"The disadvantage of all these lamps (referring to incandescent carbon lamps) lies in the fact that the thin carbon pencil has only a very short life and soon breaks at the weakest point. It is likewise naturally obvious that the carbon pencil is very quickly consumed in the air.

To remedy this evil, the carbon pencil has been enclosed in an air-tight glass bell, and later on this has been filled with gases which prevent combustion. But it appears that at a white heat the electric current causes small particles to be thrown off from the carbon pencils obtainable, and thus also, in this case a pretty rapid wearing-out takes place. At all events, the results up to this time do not yet sound very encouraging."

The opinion that incandescent carbon burners were necessarily subject to such a rapid disintegration that they would be destroyed in a short time had become so firmly fixed that when the nature of Edison's invention was made public, scientists generally did not recognize

in it any advance in the art over prior lamps, in which the burners were known to rapidly disintegrate.

Soon after the nature of Edison's invention was known in France, Du Moncel expressed the following opinion of Edison's lamp, in an article published in "La Lumiere Electrique" for January 1, 1880:

"It is, besides, difficult to admit that this horseshoe of charcoal, so slender and so delicate, does not deteriorate by a prolonged incandescence; for besides the calorific action which tends to disaggregate the carbonaceous particles, a mechanical action of the current is produced, which tends to carry them off and deposit them on the sides of the receiver, as is noticed in the tubes of Geissler."

This writer explained his reasons for the above statement in an article which appeared in the same journal for October 1, 1881, from which I translate as follows:

"Then it was suggested to employ carbon which, if now allowed to burn, is infusible in the highest heat developed in the lamps, and different arrangements of apparatus were put together at various times by King, Lodyguine, Bouliguine, Swan, Sawyer, &c., some avoiding combustion by enclosing the lamps in receptacles where a vacuum had been obtained; others, by filling these receptacles with gases unfit for combustion, as nitrogen or oxide of carbon, or simply by leaving the air shut up in the receptacles to be vitiated by an incipient combustion. All these attempts had but partially succeeded, to say nothing more, when, in 1879 the new incandescent carbon lamp of Mr. Edison was announced, and many *savants*, and myself in particular, doubted the exactness of the allegations which came to us from America."

The carbonized paper horseshoe appeared incapable of resisting mechanical shocks, and of supporting incandescence for any length of time. At this epoch, Mr. Swan himself said that up to that time he had not been able to obtain any very satisfactory results by an analogous disposition of the incandescent organ. Mr. Edison, however, was not abashed, and in spite of the lively opposition to his lamps, in spite of the bitter polemic of which he was the object, he did not cease to perfect it for practical purposes, and has at last produced lamps, which we have seen at the Exposition, and which can be admired by all the world for their perfect steadiness."

In an interview published in the New York Times for December 28, 1879, Prof. Morton expressed this opinion of Edison's invention:

> "As regards the durability of Prof. Edison's new lamps Prof. Morton was not so sanguine. 'Lamps,' said he, 'in all essential respects identical with these described by Mr. Edison have been in constant experimental use for several years past with one invariable result, namely, that while the carbon would operate successfully for periods varying from a few hours to several days, it has been found utterly impossible to render them reliably permanent.'"

About this time Prof. Morton wrote a letter to "The Sanitary Engineer," which was published on January 1, 1880. Among other things the letter contains this statement of opinion:

> "No one can more thoroughly appreciate than I do the originality of conception, the indefatigable patience and immense labor which have been involved in the series of experiments of which a sketch has been given in the 'New York Herald' of Sunday the 21st, but when I see the conclusion of these, which every one acquainted with the subject will recognize as a conspicuous failure, trumpeted as a wonderful success, I have only left before me the two alternative conclusions that the writer of such matter must either be very ignorant and the victim of deceit or a conscious accomplice in what is nothing less than a fraud upon the public. * * *
>
> P. S. When I say that the achievements described by the 'Herald' of Sunday, the 21st, constitute 'a conspicuous failure,' I do not of course mean that Mr. Edison has not now, as he had a year ago, a lot of electric lamps running at Menlo Park; but that his year's work, starting out with the most confident assertion of an accomplished success, only awaiting the granting of patents to be made public, has ended in landing him in an old method repeatedly tried and abandoned by others, and which this description furnishes no reason to believe has received any important improvement in Mr. Edison's hands."

At that time Prof. Morton apparently had no reason to believe that the high vacuum in Mr. Edison's lamp would prevent the disintegration which so rapidly destroyed the burners of prior lamps.

Extracts from an editorial, in "Nature" for February 12, 1880, entitled "Edison and the Electric Light."

> "The only difference between these lamps (referring to King of 1845, and Lodygnine of 1873) and that now brought forward is that Edison prefers a different and apparently less durable kind of prepared carbon to that employed by his predecessors, though, again, in the employment of carbonized paper he has been more than once anticipated."
>
> "The fusible nature of platinum, however, spoiled his (Edison's) efforts, and he proposed expensive alloys of iridium and osmium, only to find, what all experimenters with incandescent metals had long known, that there is a constant disintegration going on at the surface and a consequent waste."
>
> "It will be difficult to convince us that the fragile horseshoe paper cinder will resist disintegration better than the carbon used in exhausted tubes by dozens of other experimenters; * * * It must not be forgotten that even in a globe exhausted to

one-millionth of an atmosphere there yet remain many millions of millions of molecules of air enough to make the disintegration of the incandescent carbon fibre only a question of time."

The writer, from his knowledge of the art, evidently did not believe that the high vacuum would prevent disintegration sufficiently to make the filament practically durable.

At a meeting held at the Franklin Institute on January 21, 1880, Mr. Outerbridge read a paper on "The Edison Electric Light." In the discussion which followed, Prof. Elihu Thomson made these remarks:

"There seems to be little doubt that an incandescent electric light of moderate permanency is a mechanical possibility.

Whether the lamp in question answers all the requirements in this case is, of course, for the future to determine. It would seem, indeed, that a consideration of facts long in the possession of electricians and others points to the construction of a practically permanent incandescent lamp as a possibility. The earlier lamps were short-lived; those succeeding were more lasting. The element of permanency seemed to have been gradually introduced, and the results claimed by Mr. Edison point in the same direction. Whether any new departures have yet to be taken to secure a practical enduring lamp cannot as yet be determined."

As I understand it, Professor Thomson was of the opinion that in the past, increase in durability had been obtained degree by degree, and that apparently Edison's lamp was another step forward. At that time he was evidently not acquainted with the fact that slender filaments of carbon when heated to incandescence in a high vacuum would be stable and would endure for several hundred hours, although the carbon pencils of prior lamps had lasted but a few hours.

Mr. J. W. Swan, whose early and continued efforts to

make a practical incandescent carbon lamp are now historical, delivered a lecture on "Electric Lighting" before the Literary and Philosophical Society of Newcastle, on October 20, 1880. Concerning the wasting away of the carbon, he says:

"In all the various attempts to utilize the principle of the incandescence of carbon *in vacuo*, two great difficulties had stood in the way, and baffled every attempt to overcome them. One was *the rapid wearing away and consequent breaking of the incandescent carbon*, and the other *the obscuration of the lamp by a kind of black smoke*. So uniformly did these phenomena present themselves that the idea was propounded and generally accepted that the blackening of the lamp globes was due to volatilization of the carbon under the action of the enormous heat to which it was subjected. * * *

If this idea of the volatilization of carbon were founded in fact, any further attempts to render incandescent carbon lamps *durable* by means of a vacuum, would be *mere waste of time*, and durable they *must* be, to be of any practical value."

Swan says, in substance, that it was supposed that carbon burners were necessarily subject to rapid disintegration when heated to incandescence and that a practical burner could not be made unless this could be prevented.

In my opinion the foregoing citations from the literature relating to the wasting away of incandescent carbon, and to the skeptical spirit with which scientists received the announcement of Edison's invention, indicate that the substitution of a carbon filament in place of a platinum wire, in a high vacuum, would not have been an obvious thing to do or a mere matter of engineering.

14 Q. Prof. Cross, in answer 30, refers to the report of Wild, to the St. Petersburg Academy of Sciences, to show that the superiority of carbon over platinum for incandescent lighting was well understood for

years prior to the patent in suit. Please examine the statements made in the Wild report with respect to the use of platinum and carbon and say whether those statements are correct and to what extent they show a correct appreciation of the subject.

A. I have carefully noted the properties of carbon mentioned in Wild's report, which, it is alleged, make it superior to platinum as the material from which to make an incandescent burner. Wild is mistaken in giving Lodyguine the credit for being the first to suggest the use of carbon burners in place of platinum. The idea was very old and carbon had been repeatedly used. Wild also says that

> " Carbon possesses at equal temperature much greater power of radiation than platinum; the capacity for heat of platinum is superior (nearly double) that of the carbon in question, so that the same quantity of caloric raises the temperature of a small bar of carbon to a degree nearly twice that attained by a platinum wire of the same volume."

These peculiarities of carbon are of no practical effect upon the question of the superiority of carbon over platinum as the material for an incandescent burner. Mr. Wild also says that the only inconvenience in the use of carbon consists in the fact that it is consumed in the air, and that Lodyguine avoided this inconvenience by enclosing it in a sealed chamber from which the oxygen had been expelled.

It was, however, soon found that this was not the sole inconvenience, but that the wasting away of the carbon was a second and fatal inconvenience which subsequent inventors, striving to improve Lodyguine's lamp, were unable to overcome.

Moreover, Wild was wholly without appreciation of the function performed by the surface of the burner, for he says,

> " Besides, the resistance of the carbon in question, as a conductor of electricity, is nearly 250 times greater than that of platinum; it results that the small rod of carbon may be fifteen times thicker than a platinum bar of the same length, and that the current traversing it will engender the same quantity of heat."

The statement that the same amount of heat would be developed is correct, but with the amount of heat which would make the platinum burner incandescent, the carbon burner, with fifteen times the surface, would give out no light. Any one following Wild's directions in this respect would have certainly failed. Wild's report contributed nothing new to the art and was inaccurate in some respects and misleading in others, and altogether shows that he did not have a proper appreciation of the subject which he undertook to explain.

14 Q. The statement of M. Jobart as to the De Changy incandescent lamp appears at various points in the record. I call your attention to the Belgian Patent of De Changy No. 3244, dated August 28, 1856, which I now hand you. What was the construction of De Changy's incandescent lamp, as shown by this patent, and do you know of any other patent or publication except the Jobart article, describing this lamp?

A. De Changy's incandescent lamp consists in the main of a platinum wire burner in the form of a spiral, which is inclosed in a cylindrical glass chamber, the two ends of which are closed by metallic discs held in place by metallic rods. The two conductors which serve to convey the current to the burner pass through one of the metallic discs, and are insulated from it, and have hook-shaped ends, by means of which the lamp can be suspended from the conducting wires leading from the battery or other generator. Another portion of the apparatus consists of spools of wire, the ends of which terminate in hooks. By first attaching these spools to the conductors, and then suspending the lamp from the former, resistance is introduced into the lamp circuit which reduces the strength of the current and the intensity of the light. From the specification I understand that the lamp chamber is not intended to be air-tight; that its only purpose is to protect the spiral from mechanical injury, from mechanical shocks, and probably to prevent danger of explosions of fire damp, since the lamp is described in the patent as a mining lamp.

Although I have made quite extended research in the literature of electric lighting, including foreign patents, I have been unable to find any reference to De Changy's lamp other than that contained in his Belgian Patent and in Jobart's article communicated to the French Academy, or descriptions obviously obtained from the same sources.

Adjourned until Tuesday, July 22, at 11 A. M.

July 22, 1890.

Met pursuant to adjournment.

Adjourned until Saturday, July 26, 1890, at 11 A. M

July 26, 1890.

Met pursuant to adjournment.

Adjourned until Monday, July 28, 1890, at 11 A. M.

Counsel for complainant offers in evidence the following matters:

An extract from a paper on "Dynamo Electric Apparatus" by Higgs and Brittle, published in Transactions of the Institute of Civil Engineers, Vol. 52, London, 1878, and the same is marked Complainant's Exhibit Higgs and Brittle paper.

Objected to as immaterial, incompetent and inadmissible, and more especially because the exhibit purports to be an *extract* only from the paper in question, the context being withheld from the Court.

Complainant's counsel offers to defendant's counsel a complete copy of the paper referred to, so that he can introduce, by the cross-examination of the witness, such additional matters from the context as he thinks necessary to explain the extract put in evidence.

Also a letter by William Trant headed "The Divisibility of the Electric Light," published in "Nature" for November 21st, 1879, Vol. 19, page 52, London 1879, and the same is marked Complainant's Exhibit Trant letter.

Objected to as immaterial, incompetent and inadmissible.

Also the translated extracts from Chapter XIII. of Fontaine's book entitled "Lighting by Electricity" 2d Edition, Paris, 1879, given by the witness in answer to question 6, and the same is marked Complainant's Exhibit Extracts from Chap. XIII., 2d Edition of Fontaine.

Same objection as to the "Higgs & Brittle Paper" above.

Same offer by complainant's counsel as to the "Higgs & Brittle Paper" above.

Also extracts from Professor Henry Morton's Report to the Light House Board, dated November, 29th, 1879, and published by the U. S. Government in 1880, and the same is marked

Complainant's Exhibit Morton's Government Report.

Same objection.

Same offer.

Also a translation into English of Chapter III. of a work on Electric lighting by Alex. Bernstein, Berlin, 1880, and the same is marked Complainant's Exhibit Chap. III. Bernstein's Book.

Same objections.

Same offer.

Also a copy of the drawing and a translation into English of the specification of the Belgian patent of De Changy No. 3244, dated August 28th, 1856, and the same is marked Complainant's Exhibit De Changy Belgian Patent.

Objected to as immaterial, incompetent and inadmissible.

Also a translation into English of an extract from a paper on "Electricity in Relation to Life" by Dr. Werner Siemens, published in "Elekticitatslehre," Munich, 1879, and the same is marked Complainant's Exhibit Siemens' Paper.

Same objections. Also objected to because the context of the article is not produced.

Same offer as to "Higgs & Brittle Paper" above.

Also a paper "On the Progress of the Electric Light" read by R. E. Crompton before the Royal United Service Institution, January 28th, 1881, and the discussion thereon, published in the "Journal of the Royal United Service Institution," Vol. XXV., London, 1882, and the same is marked Complainant's Exhibit Crompton's Paper and Discussion.

Objected to as incompetent, immaterial and inadmissible, both on general grounds and especially because complainant has no right to bring before the Court the declarations and opinions of the various persons named in the

paper in question, which is of later date than the patent in suit, without producing the said persons and submitting them to cross-examination under oath.

Also a paper by Professor H. A. Rowland and George F. Barker "On the Efficiency of Edison's Electric Light," published in the "American Journal of Science," Vol. XIX., April 1880, and published in advance in the "New York Herald" for March 27th, 1880, and the same is marked Complainant's Exhibit Rowland and Barker Paper.

Same objections as to the last-named exhibit. The further objection is made, on the assumption that, if the George F. Barker who is one of the authors of the paper in question is the Professor Barker who has twice been called as a witness in this case, the statements by him made in the paper cannot properly be admitted in evidence unless the witness is recalled for further cross-examination.

Also a lecture on "Edison's Electric Light" by Professor Barker before the Franklin Scientific Society, and published in the "New York Herald" for March 25th, 1880, and the same is marked Complainant's Exhibit Barker's Lecture.

Same objections as to the last exhibit.

Also an extract from an editorial entitled "Gas vs. Electric Lighting," published in the "Telegraphic Journal" for October 15th, 1878, and the same is marked Complainant's Exhibit Telegraphic Journal Article of October 15th, 1878.

Objected to as incompetent and immaterial; also as not admissible when separated from its context.

Same offer as to "Higgs & Brittle Paper" above.

Also an extract from an article in "Engineering" for January 2d, 1880, entitled "The Brush Electric Light," and the same is marked Complainant's Exhibit Engineering article of January 2d, 1880.

Same objections.

Same offer.

Also an extract from an article in "Engineering" for January 9th, 1880, entitled "Edison Electric Light," and the same is marked Complainant's Exhibit Engineering Article of January 9th, 1880.

Same objections.

Same offer.

Also extracts from an article in "The Engineer" for February 13th, 1880, entitled "Mr. Edison on Electric Light," and the same is marked Complainant's Exhibit Engineer Article of February 13th, 1880.

Same objections.

Same offer.

Also an article by Henry Morton entitled "Electricity in Lighting" published in Scribner's Magazine for August, 1889. and the same is marked Complainant's Exhibit Morton's Scribner Magazine Article.

Objected to as incompetent and inadmissible, especially on the ground that Dr. Morton has been produced as a witness for the defendant, and when upon the stand might have been cross-examined as to any of the statements contained in said magazine article. He was then cross-examined as to some of the statements of said article, and presumably as to all that the complainant's counsel deemed material to their case. It is deemed improper, now that the witness has left the stand, and has no opportunity for explaining the other parts of the said article, and notably his utterances which make reference to the work which Mr. Edison has done in connection with electric lighting, that complainant should introduce such parts into the record.

Complainant's counsel replies that the reason for offering the complete article in evidence will

be found in the evidence of the defendant's witness, Dr. Morton, in answer to cross-question 74 of his deposition.

It is stipulated that typewritten copies may be used in place of the original publications of the foregoing exhibits; also that the exhibits offered as translations are correct translations; and also that the publications were made and the patent granted as stated in the offers of the exhibits; this stipulation being subject to the correction of errors which may be found in any of the exhibits at any time before the hearing.

The same stipulation is made with respect to the various paper exhibits offered by the Complainant's Counsel in the cross-examination of the defendant's witnesses.

July 28, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

Cross-examination of the Witness, Charles L. Clarke, by General Duncan:

15 x-Q. Are you in the employment of the Edison Company otherwise than as an expert retained in this case?

A. I am retained by the Edison Company as an expert in the patent litigation relating to electric lighting and power generally.

16 x-Q. Are you employed upon a salary, or how?

A. I am only paid for the time I am actually employed.

17 x-Q. I assume that you have made a very thorough examination of the literature pertaining to the art of incandescent electric lighting and generally to the subdivision of the electric light, as such literature ex-

isted down to the date of Edison's application for the patent in suit?

A. I have tried to make myself familiar with the history of the art up to that time, and believe that I am reasonably familiar with it.

18 x-Q. Have you quoted in your direct testimony from all of the authorities who had written upon this subject prior to the date of Edison's application?

A. I hardly think so. That would appear to me a very difficult task to undertake. The literature on this subject is very voluminous, and I have no doubt that there are works relating to it of which I have not even heard. I have merely done what I could, by quoting from the literature of the art, to give a correct idea as to its condition.

19 x-Q. How extensive did you find the literature on this subject to be?

A. I found works in English, French and German which treated of subdivision, together with electric lighting generally, and also found it considered in various periodical publications extending over perhaps twenty years. The subject is only occasionally referred to in the printed literature until about the year 1873. From this time on the attention of electricians was very generally directed to the problem of the subdivision of the electric light, and it was frequently mentioned in the literature of the art.

20 x-Q. How many different authorities should you think had treated on the subject prior to November 4, 1879?

A. That I cannot say with any exact degree of accuracy, because there are so many letters and articles scattered through various periodical publications of which I have no memorandum. But I should say that there were perhaps eight or ten different authors whose writings upon the subject attracted much attention and whose opinions had considerable influence upon the art.

21 x-Q. In point of fact did you not examine the writings upon this subject of a very much larger number of persons than eight or ten?

A. I did read other articles in which the subject was mentioned either incidentally or quite superficially, but I do not recollect anything concerning the subject so complete as those articles which I have in mind, to which I before referred.

22 x-Q. Is it not a fact that in your investigations you found a large number of articles which treated in a more or less complete manner on the problem of the subdivision of the electric light, and to which you made no reference on your direct examination?

A. There were quite a number of other articles in which the question of subdivision was considered, but I should say considerably less rather than more completely than in those to which I before referred. Those articles from which I have quoted in my direct examination, in my opinion, give a correct idea of the state of the art prior to the date of the patent in suit.

Last sentence objected to as not called for by the question.

23 x-Q. All told, how many articles bearing upon this subject did you find?

A. That is a very hard question to answer, as I have no memoranda relating to it. I may perhaps have come across twenty-five articles in which subdivision was mentioned, perhaps more.

24 x-Q. You seem to have laid great emphasis in your testimony upon the opinion of Fontaine, whom you have included in your list of "scientific men." What claim had Fontaine in 1878 or 1879 to be regarded as a scientific man?

A. Personally I know nothing positive concerning Fontaine, other than the impression which I have gained concerning him from reading several books which he has published and articles which he has contributed to technical journals. Whether the term "scientific man" in the broad sense applies to Fontaine I do not know; but from reading his book on electric lighting, published in 1877, I should say that the term is entirely appropriate.

25 x-Q. Have you read any book of his published prior to his work on electric lighting?

A. Yes. A work descriptive of some of the exhibits at the Vienna Exposition. This was published, I think, in 1873.

Adjournment for lunch.

Resumed.

26 x-Q. Do you know whether Fontaine, at the date of the publication of the first edition of his work on electric lighting, was a member of any scientific society?

A. I do not.

27 x-Q. Do you find any evidence on the title page of said book, or elsewhere in said publication, to show that he laid claim to being a member of any such society?

A. No.

28 x-Q. Is the same true of the second edition of Fontaine's work on electric lighting?

A. Yes.

29 x-Q. So far as you know did Fontaine maintain any other substantial relation to the art of electric lighting in the years 1878 and 1879 than that of a business gentleman as manager or superintendent of a company engaged in the development of the art and the production of dynamo machines? And was it not while he was so engaged that his book upon electric lighting, to which you have frequently referred, appeared?

A. I have understood that at that time Fontaine was actively engaged in developing the business of electric lighting, more particularly the improvement, manufacture and introduction of the Gramme dynamo. Apparently at that time he was also carrying on experiments looking to the further improvement of methods of lighting, as is indicated by the recital of his attempts at subdividing the light, published in the first edition of his book.

30 x-Q. As you understand the matter was not M. Gramme the electrician of the company with which Fontaine was working?

A. I do not know what M. Gramme's relations with the company were at that time.

31 x-Q. Have you any means of knowing whether Fontaine's book on electric lighting was written by Fontaine himself, or (as is generally understood to be the case with Prescott's book on electricity in this country) written by other persons than the reputed author—but published under Fontaine's name?

A. I have no positive means of knowing other than the evidences which the books itself contains. The title page states that it is written by Fontaine. In the preface and other parts of the book (I am referring to the 1877 edition), the author refers to himself in the plural number as "we," etc. The word "we," I think, expressly refers to Fontaine, for I find on page 181 of Higgs' translation the following:

> "We are about to repeat all these experiments substituting for a battery a Gramme machine constructed to give the best useful effect; but the imperfection of the lamps, the difficulty of obtaining good contacts, the too minute care to be taken at the commencement of each operation, led us to previously design a lamp more commodious and slightly more practical than that of M. Konn. This lamp, which we represent in Figure 48, is at present under construction by M. Bréguet."

Figure 48 referred to in the text is entitled "Fontaine's Lamp." To my mind this clearly indicates that the writer of the book, who calls himself "we," was Fontaine.

32 x-Q. Would you consider the mere fact that Prescott had published over his name such a book as "Prescott's Electricity and the Telegraph," but which he had procured others to write, justified you in drawing the inference that Prescott is a scientific man?

A. I think that it would, until I had sufficient evidence to convince me that he did not write the book.

33 x-Q. If you knew the fact to be that he had procured other persons to write the principal chapters of that book, would you regard him as a scientific man, simply because he had produced such a book?

> Objected to as immaterial, the book not having been referred to by the witness on direct examination.

A. No, I should want evidence, aside from the book, as to his ability, before I should consider him a scientific man.

34 x-Q. What do you know about Higgs that justifies you in calling him a scientific man?

A. At the time that Higgs translated the first edition of Fontaine's work and for several years afterwards, he wrote several books and articles upon the electric light and the dynamo machine, which were, as I understand, considered to be of considerable merit. I notice also on the title page of a paper which was read by him in 1878, on "dynamo-electric apparatus," that he had the titles of L. L. D. and Assoc. Inst. C. E. I should say that in view of these circumstances Higgs might properly be called a scientific man.

Adjourned until Tuesday, July 29, 1890, at 11 A. M.

July 29, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

Cross-examination of the Witness, Charles L. Clarke, by General Duncan, continued:

35 x-Q. Are you aware of the fact, or have you ever heard that Higgs was expelled from the Society of Civil Engineers?

A. I was not aware that such was the case.

36 x-Q. Did you, in your search, find anything in the writings of Becquerel or De La Rive or Kohlrausch bearing upon the subject of the divisibility of the electric light?

A. I do not now remember of having come across anything upon the subject written by De La Rive or Kohlrausch. But I believe that I did find an article written by Becquerel concerning Lacassagne and Thiers' lamp. I think that in that article something was said on the subject of subdivision, but am not positive that such is the case.

37 x-Q. Would you regard the persons named in the last question as authorities on the subject of electric lighting, or of electricity generally?

A. I should certainly regard them as authorities on the general subject of electricity from a purely scientific standpoint, but should not necessarily regard them as at all competent to express an opinion upon the practical application of electricity to commercial purposes. It is very often the case that a person of high scientific attainment is entirely unable to apply his knowledge to any practical useful purpose, and I do not know that the persons mentioned were particularly competent to do this, or to express an opinion as to the possibility of its being done by others.

38 x-Q. Do you consider that Higgs was specially competent to express an opinion on the practical application of electricity to commercial purposes; and, if so, what in his career justifies that conclusion on your part?

A. From the fact that Higgs had been a member of the London Society of Civil Engineers, I should say that he was a man who was considered to be qualified to consider scientific facts in their practical application; and I think that what he has written on the subject of electric lighting shows that he was well acquainted with the subject as it was known to the art at the time that he wrote concerning it.

39 x-Q. Do you agree with his statement of the law of the heating effect of the electric current, as given on page 214 of his work on electric lighting, being a part of Chapter X., put in evidence heretofore by the complainant ?

A. I think that at the time the book was written (1879) this statement was understood by the art to be entirely correct, as it certainly was, if we assume the resistance of the lamps to remain constant.

40 x-Q. The statement also assumes, does it not, that the current strength remains constant under the various conditions as to number of lights set forth in the statement?

A. Yes.

41 x-Q. Understanding Higg's statement of the heating effect of the electric current as applied to electric lighting to be thus qualified, is his statement true to-day ?

A. Yes. The law of the heating effect as stated by Higgs, and thus qualified, is true to-day; but the conclusion which Higgs states to be a consequence of this law is not at all true to-day. Higgs concludes that as a result of this law there would be such a rapid falling off in the amount of light produced, when a division of the current among a number of lamps was attempted, that extensive subdivision would be impossible. To-day, however, it is known how to prevent this rapid falling off in the amount of light, and to make subdivision possible.

42 x-Q. Under the conditions of current assumed in Higgs' statement of the law, would there not be that same rapid falling off which Higgs speaks of, even if the lamp used were any one of the modern commercial incandescent lamps ?

A. Undoubtedly, if the current which is to-day requisite to heat a 16-candle-power lamp up to its normal incandescence, were divided among two or three such lamps, there would be a great falling off in the total amount of light. But to-day we know how to divide that same amount of current among several lamps of less than 16-candle-power capacity so that it will produce the same total amount of light as would be produced if the total current were passed through the single 16-candle-power lamp, which, so far as I know, was generally conceded to be impossible of accomplishment when Higgs wrote his book.

43 x-Q. Suppose, however, that you were to-day running one of the Edison Company's 16-candle-power lamps with a current just sufficient to develop the normal illuminating power of the lamp, do you know of any method by which you could divide that same current among two or four such lamps, without there being a great falling off in the total illumination to wit: a falling off equal to that contemplated by the law set forth by Higgs in chapter X. of his book.

A. Assuming that the question refers to lamps which are absolutely identical in all respects, and, more particularly, of the same candle-power, and with burners of the same length, cross-section and resistance, I know of no way by which the amount of current required to bring one lamp to its normal incandescence can be divided among a number of such lamps, without a great falling off in the total amount of light comparable to the rapid decrease in the light mentioned by Higgs. But if the question relates to lamps alike only as to their candle-power, then we do know to-day how to divide the amount of current necessary to operate one 16-candle-power lamp, constructed in one manner, among a number of lamps constructed in another, and suitable, manner, each of which shall also be of 16-candle-power. This ability to increase the number of lamps and the total amount of light with a small current is one of the valuable features of the modern system of incandescent electric lighting, resulting as it does in a great saving in the cost of the conductors leading from the generator to the lamps.

Adjourned for lunch.

Resumed after lunch.

44 x-Q. I understand you to indicate by the latter part of your last answer that with the knowledge now possessed by the world it is possible to so utilize the amount of current which is necessary to bring one of Edison's 16-candle-power lamps to normal incandescence as to cause it to bring to incandescence several 16-candle-power lamps, and that this result is to be attained by changing the construction of the lamps according to the number that may be employed. Does this correctly state your view?

A. Yes. I had in mind 16-candle-power lamps of low resistance, and also those of low economy, which required a certain amount of current. By making lamps with burners of smaller diameter and less surface and of higher resistance than the burners of the lamps first mentioned and by raising them to a higher temperature the same amount of current is sufficient to supply several such lamps at 16-candle-power. By proceeding in this manner, instead of attempting to divide the current among several lamps of like construction and of large diameter and low resistance, as was done prior to the date of the patent in suit, it became possible to supply a number of lamps with a small current resulting in the diminution of size and cost of conductors.

I also had in mind prior lamps which had carbon burners of large cross section, and which required a comparatively large current to heat them to incandescence as compared with the filamentary burners of modern lamps, which require a comparatively feeble current.

45 x-Q. By any of the known methods of constructing lamps or distributing the current, how many 16-candle-power incandescent lamps can be economically burned with that amount of current which is requisite to bring to normal incandescence one of the Edison Company's ordinary commercial 16-candle-power lamps?

A. Of course it must be conceded that the Edison 16-

candle-power lamp which is most commonly in use to-day is so constructed as to require the smallest possible quantity of current consistent with other requirements which go to make up a practically commercial lamp. But lamps made by the Edison and other companies are quite extensively used which require a current sufficient to supply quite a number of lamps like those most commonly in use. The art of subdividing the current has reached a very high degree of perfection, and has approached the point where progress is exceedingly slow. Indeed, after the method by which subdivision could be accomplished was known, nothing further was done, so far as I know, excepting to improve the durability and the economy of the lamps.

The foregoing answer objected to as not responsive.

Adjourned until Wednesday, July 30, 1890, at 11 A. M.

New York, July 30, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

Cross-examination of the Witness, Charles L. Clarke, continued:

46 x-Q. I repeat my last question. By any of the known methods of constructing lamps or distributing the current, how many 16-candle-power incandescent lamps can be economically burned with that amount of current which is requisite to bring to normal incandescence one of the Edison Company's ordinary commercial 16-candle-power lamps?

Objected as immaterial and irrelevant.

A. If by the "ordinary commercial 16-candle-power lamps," referred to in the question, is meant those lamps which are most generally used in Edison electric light plants, I do not know that the art is to-day acquainted with any method by which practical commercial lamps can be made so that several of such lamps can be operated with the same amount of current as is at present required for one of the "ordinary" lamps mentioned.

47 x-Q. How many lamps of smaller illuminating power than 16 candles and adapted for domestic illumination could be run with the same amount of current that is required to bring to normal incandescence one of the ordinary commercial 16-candle lamps of the Edison Company?

A. I do not think that it is at the present time known how to construct commercial lamps of less than 16-candle-power, so that several of such lamps could be operated by the same amount of current as is required for one "ordinary" 16-candle-lamp. The efforts of the art have been continually directed towards obtaining lamps having burners of exceedingly small cross section, which would therefore require the least possible amount of current for their operation. A limit seems to have been reached which would make a further reduction in the amount of the current required a difficult undertaking. I do not wish, however, to be understood as saying that it is at all impossible or improbable that this will be done, if we are to judge from what has been accomplished since the art of modern incandescent lighting began. Within that time the amount of current requisite for an ordinary 16-candle-power lamp has been reduced about forty per cent.

48 x-Q. When was this reduction effected, and by what means?

A. This reduction in the amount of current required to supply an ordinary modern 16-candle lamp (by modern lamp I mean one made since the date of the patent in suit) was not arrived at all at once; but there has been a gradual reduction as the durability of the lamp has been increased by improved methods of manufacture.

The increase in durability made it possible to reduce the cross-section of the filament and operate at a higher degree of incandescence and therefore to reduce the strength of the current.

49 x-Q. In the actual working of a large plant of modern incandescent lamps is the same amount of current used when all the lamps are turned on (or burning) which is used when only a single lamp of the plant is burning?

A. No. The amount of current required is proportional to the number of lamps which are burning. One thousand lamps require one thousand times the strength of current necessary for one lamp.

50 x-Q. In your answer to Q. 6, in which you have quoted certain paragraphs from Chapter X. of Higgs' work on the electric light you say, in commenting upon the quotations:

"Higgs apparently was of the opinion that subdivision was altogether impossible, even by arc or incandescent lamps."

On referring to Higgs' book I find that the context of the passages which you quote is as follows:

> "The division of the electric light is a term the true rendering of which should be the 'division of the electric current' to produce numerous small light centers instead of one or more powerful lights. Much nonsence has been talked in relation to this subject. Some inventors have claimed the power to 'indefinitely divide' the electric current, not knowing or forgetting that such a statement is incompatible with the well-proven law of conservation of energy.
>
> Whether the electric current be utilized in the production of light, either by means of the voltaic arc or of incandescence, the production of a certain amount of light depends upon the amount of current passing, not directly, but in such a proportion that offers speedy limit to the number of lights to be obtained. The law is a very simple one. It is that the heating effect of the electric current

will be proportional to the square of the amount of current multiplied by the resistance, both expressed in convenient units. Suppose, then, that two lights exist of a certain power, each on two circuits derived from a main circuit, and that two more lights are required to be added, one in each of another two circuits again derived from the main circuit. The current formerly passing in each of the circuits when only two existed will be halved by the introduction of the other lights, and, according to the law, the heating effect in each circuit will be only one-fourth of that occurring with two lights. Actually, as the lighting effect bears to the heating effect much the same relation as the heating effect does to the amount of current, the decrease of light is much greater. With a given current source, the division of the electric current is, therefore, anything but indefinite.

Even with gas, which possesses the great advantage of yielding a large number of small lights, the greatest economy is obtainable with concentrated lights; and it is well known that the ignition of extra burners on a pipe of small diameter materially reduces the light in those burners already ignited. Though noticeable in a much less degree because obeying a different law, with a fixed supply of gas the reduction of light arising from the ignition of fresh burners is appreciable, and shows that the electricians who claim indefinite subdivision exceed what is required or possible."

Is it not a fair inference from these fuller statements of Higgs that he did not deem the, subdivision of the electric light impossible, but only that it was impossible to carry the subdivision on "indefinitely?"

A. No, I cannot draw that inference from reading the matter quoted in the question from Higgs' book. The author in the beginning defines subdivision as he understands it as follows:

"The 'subdivision of the electric light' is a term the true rendering of which should be 'the division of the electric current' to produce *numerous* small centers instead of one or more powerful lights."

(The italics are mine).

After thus stating that the problem properly related to *numerous* small lights, he goes on to state the law, which was accepted by the art at that time as being correct, to the effect that if the current was divided among several lamps, the falling off in the amount of light produced by each lamp would be very great, in fact greater than the square of the number of the lamps among which the current was divided. The author, in illustration of the effect of thus dividing the current, states that when the amount necessary for two lamps is divided among four similar lamps, each will give off less than one-fourth the amount of light before given off by each of the two lamps.

In view of the fact that Higgs defines subdivision as relating to *numerous* small lights; that he translated the first edition of Fontaine's work, which contains experiments proving that when the current was divided among three or four incandescent lamps, the falling off in the amount of light produced was so great as to render subdivision practically impossible; and also that the matter quoted from his book in the question contains a statement of the law from which this great diminution in the amount of light resulted, and his acceptance and illustration of the correctness of this law, I am of the opinion that when the author says that the division of the current is "anything but indefinite," he uses the term sarcastically, and actually intends it to be so considered, believing, as I think he did, that the reader would understand from his definition of subdivision and his illustration of the results which would follow from attempting to accomplish it, that in his (Higgs') opinion subdivision, either by arc or incandescent lights was altogether impossible.

Adjourned for lunch.

Resumed.

51 x-Q. In your direct testimony you have spoken frequently of the "subdivision of the electric light." What did you mean by this expression?

A. I think that I have used the expression in the sense in which it has generally been used in the art of electric lighting in the past. As I understand it, the expression has been generally understood to relate to the production of small electric lights of such a character that quite a number could be operated from a single source of electricity, and at a reasonable distance from it, and which should in other respects be practically commercial lamps. All of which has been more fully set forth in my answer to 3 Q.

52 x-Q. Please state what you mean in your answer by the terms "small" ("small electric lights") "quite a number" and "reasonable distance."

A. By "small electric lights" I mean those lights which would have an illuminating power about equal to an ordinary gas-jet, so that they would be conveniently available for the lighting of interiors. By "quite a number" I mean such a number of lights, each of a power equal to a gas-jet, as would be required to light an ordinary-sized building or factory, say fifty or one hundred lights. By "reasonalo distance" I mean that the lights located throughout such a building could be supplied from a dynamo located in the basement or ell of such building, these being the places where the dynamo machine and engine would be most conveniently located.

53 x-Q. Then you do not consider that it is necessary, or that it ever was necessary, to the practical solution of the problem of the subdivision of the electric light, that the lamp used should be so organized, or that the means for generating the current should be such, or that the mode of distributing the current when generated should be such, that the number of lamps run from a single source of current-supply should be approximately equal to the number of gas-jets which in

ordinary municipal illumination by gas are supplied from a single gas works?

A. No. I do not think that it ever was considered that the problem of subdivision required for its solution that the number of lamps and their distance from a single source should be comparable to the number of gas-jets supplied by a single gas works, and their distance from the same.

54 x-Q. Then, in your opinion, the ability to produce fifty separate lights with current supplied from a single generator, such lights being distributed through different parts of an ordinary building, would be a practical solution of the problem of the subdivision of the electric light, even if it were not possible to supply a larger number of lights from the same source. Is that correct?

A. As the question stands it is not entirely correct. If each lamp had an illuminating power about equal to a gas-jet; if they were durable, cheap and economical enough to make them commercially practical, and if they were not at all liable to get out of order, and were so simple in their construction that the public could look after them, and also if they did not require too large and expensive conductors, I should say the ability to produce fifty such lights with a current from a single generator would be a practical solution of the problem of subdivision.

55 x-Q. Why do you say that the problem of subdivision of the electric light requires that each light should be approximately of the same illuminating power as the ordinary gas-jet?

A. Because, as I understand it, the art of subdivision has always been considered as relating to the production of electric lights which should be peculiarly suited to lighting ordinary interiors. Long experience with gas-lighting had resulted in the general adoption of what is commonly known as a "gas-jet" (averaging about 16-candle-power), because it was found to be, all things considered, best suited to lighting ordinary interiors.

Before the problem of subdivision was solved, the public was in possession of the arc light, which was entirely suited to out-of-door-lighting, and attention was also turned to the lighting of interiors by the electric light, and it was assumed that this could be best accomplished with electric lights of a power about equal to that of gas-jets, which had for many years been used with satisfactory results.

Adjourned until Thursday, July 31, 1890, at 11 A. M.

New York, July 31, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

Cross-examination of the Witness Charles L. Clarke continued:

56 x-Q. Suppose in the year 1879 Mr. Edison had made fifty incandescent lamps of the character set forth in the patent in suit, having each a power of 100 candles, and on trial had found that he could run them on a single circuit, and this had been all that he had done, would you have regarded it as a practical solution of the problem of the subdivision of the electric light?

Objected to as immaterial, and as not warranted by the facts.

A. If, in 1879, Mr. Edison had made fifty incandescent lamps, each of 100-candle-power, after the method set forth in the patent in suit, and had found that they could be operated by the current supplied from a single source, I think that the accomplishment of this result would have been regarded as a solution of the problem of subdivision.

57 x-Q. Then you do not regard it as at all necessary to the solution of the problem that the lamps

made should be as low in illuminating power as the ordinary gas-jet?

A. I do think that it was necessary that the art should know how to make practical commercial lamps of an illuminating power about equal to a gas-jet before it could be said that the solution of the problem of subdivision was accomplished.

In my opinion, if Edison had made 100-candle-power lamps after the manner described in the patent, the art, with the exercise of good skill and judgment, and without further instruction, would have at once known how to construct fifty similar lamps, each having a power about equal to a gas-jet, which could be supplied from a single source of electricity. In my opinion a method of constructing fifty practically commercial 100-candle-power lamps, operative from a single source, which would likewise sufficiently instruct the art how to make fifty similar lamps, each of a power about equal to a gas-jet, and also operative from a single source, would be considered as a practical solution of the problem of subdivision.

Adjourned for lunch.

The deposition of the witness is suspended to take the deposition of Major Eaton.

Adjourned to August 1, 1890.

New York, August 1, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

Cross-examination of the witness Charles L. Clarke continued:

58 x-Q. By your last answer I should judge that you hold the opinion that if one had devised a lamp of 100-

candle-power, fifty of which could be run on a single circuit, it would not have involved invention to make fifty other lamps embodying the same principles of construction, but having a power of only sixteen candles each. Is such your opinion ?

A. I do not think that it would have required invention, providing the 100-candle-power lamps were practically commercial lamps, and also providing the method of constructing the 100-candle-power lamps would have been instructed the art, with the exercise of skill and judgment, how to make similar practically commercial lamps, each of only sixteen-candle-power.

59 x-Q. So far as regards the principles of construction involved in the lamps, do you understand that there is any difference between a commercial 100-candle-power lamp made under the Edison patent in suit, and a sixteen-candle-power lamp made under the said patent?

A. I do not consider that there is any difference involved in the principles of construction of commercial 100-candle-power and 16-candle-power lamps made under the patent in suit.

60 x-Q. Practically can you put upon a single circuit as many Edison 100-candle-power lamps as you can of the Edison 16-candle-power lamps?

A. No, not if in both cases the same amount of current is to be used, which I take it is assumed in the question; but the number of 16-candle-power lamps which can be connected with a circuit in place of the 100-candle-power lamps and which can be operated by the same current, will give the same total amount of light. To illustrate: If a certain amount of current will operate 16 100-candle-power lamps the total illuminating power will be equal to 1,600 candles; this same amount of current will also operate 100 16-candle-power lamps, which also gives a total illuminating power of 1,600 candles.

61 x-Q. Would the electro-motive force of the current be the same in the two cases?

A. It would be the same in the two cases, likewise, the amount of electrical energy supplied to the lamps and their economy would be the same.

62 x-Q. In order that 100 Edison 16-candle-power lamps should be capable of use on the same circuit on which 16 100-candle-power lamps might be used, without change in the quantity or electro-motive force of the current, it would be necessary, would it not, that the resistances of the two sizes of lamps should be to each other inversely as their illuminating powers?

A. Yes.

63 x-Q. This substitution of 100 16-candle power lamps for 16 100-candle power lamps, without change in the quantity or electro-motive force of the current, would be a practical illustration, would it not, of what is known and what you have spoken of as "the subdivision of the electric light"?

A. I should say that it was an excellent illustration as to how subdivision is accomplished by means of a suitable lamp.

64 x-Q. Do you mean in other words to say that if you have given a suitable lamp you can subdivide the light by changing the resistance of the burner used in the lamp?

A. No. Change in resistance only would not be sufficient; the length, diameter and surface of the burner would also have to be taken into consideration.

65 x-Q. In other words, as I understand you, in order to subdivide the light of one incandescent lamp among several incandescent lamps embodying the same principles of construction, it is necessary that the burners of the several smaller lamps shall differ from that of the single larger lamp not only in the matter of resistance but also in the matters of length, diameter and surface?

A. Yes, provided, however, it is assumed that in the two cases the lamps are to be operated under the same electro-motive force, and the same economy, and that the current required to supply one lamp shall be the same as the total amount of current required to supply such a number of the subdivided lights as will give a total candle power equal to that of the single lamp.

66 x-Q. Suppose, however, that you were not restricted to the use of the same electro motive force, or to the same quantity of current, in the two cases, would it still be necessary to make changes in the construction of the burner in order to divide up the light given by one large lamp among several smaller lamps?

A. Yes. I think that for practical commercial reasons that, as we divide a single burner into several burners of less illuminating power, it would be essential that we should increase the resistance and diminish the surface of the burners of less power in order not to increase the size and cost of the conductors above what would be requisite to supply the undivided burner.

67 x-Q. What rule do you find laid down in the patent in suit for enabling a person to determine the amount of change which is to be made in the resistance or in the surface, or in the length or thickness of the burner of an incandescent lamp in order to subdivide among several lamps that quantity of light which one large lamp is capable of generating?

A. I do not find any specific directions on this point set forth in the patent in suit, and I do not think that they were at all necessary. In my opinion, if a person skilled in the art had, at the date of the patent, constructed a lamp according to the directions therein set forth, he would, after ascertaining its candle power and the electro motive force and current necessary to operate it, have at once known what dimensions to give to another burner of any other desired candle power and requiring a given current and electro-motive force to operate it.

68 x-Q. By this do you mean that in your opinion the knowledge existing in the prior state of the art was such that if a person experimenting under the patent in suit found that he could make one operative lamp of a given illuminating power, say of 250-candle-power, he would from such prior knowledge, and in the absence from the patent of any rule in the premises, have known of what size and proportions to make the burners of other lamps so that their united illuminating power should be equal to that of the one lamp first named.

A. Yes, I think that he would have known how to do this, because he would have had something tangible in the form of a practically operative and commercial lamp, the characteristic features of which are set forth in the patent in suit, to which to apply his theoretical knowledge of electricity, which, in my opinion, would be sufficient for the purpose. In my opinion the exercise of ability in this direction would hardly have been called in play prior to the date of the patent in suit, in the absence of any practical incandescent lamp construction, or if it were I do not think that it would have accomplished anything toward subdivision.

69 x-Q. When you answered 54 x-Q. did you assume that the fifty lamps were to be arrranged in multiple arc?

A. Yes, I had in mind lamps arranged in multiple arc.

Further hearing adjourned to Monday, August 4th, 1890, at 11 A. M.

NEW YORK, Aug. 4, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS EXAMINATION OF MR. CLARKE, CONTINUED BY GENERAL DUNCAN:

70 x-Q. Suppose the fifty lights referred to in your answer to 54 x-Q. had had an illuminating power of, say, *six or ten times the ordinary gas-jet*—would the production of these lamps arranged in multiple arc and operated on a single circuit, even if it had not been possible to supply a larger number than fifty from the

same source, have been a practical solution of the problem of subdivision of the electric light?

A. I think that this would have been a solution of the problem of subdivision, provided the method of making such lamps would have instructed the art, with the aid of the knowledge already possessed, how to make practically commercial lamps, each having the power of a gas-jet, and otherwise so constructed that when a sufficient number of them were connected to the circuit so as to give a total amount of light equal to the total amount produced by the fifty larger lights, the amount of copper in the conductors, the total current, the electro-motive force, and economy in the two cases would be the same.

71 x-Q. With the qualifications stated in your last answer, in regard to the character of the lamp, would it not in your opinion have been a practical solution of the problem of subdivision of the electric light if the man first making the lamps had made but fifty, and had arranged them only *in series*, and if the lamps had had each an illuminating power of say six to ten times that of an ordinary gas-jet?

A. Of course, if the character of the fifty lamps in series mentioned in the question, had been such as would have instructed the art how to construct practical lamps of the power of a gas-jet, so that a sufficient number of them could be connected in multiple arc on a circuit so as to give the same total amount of light as the fifty large lamps, and with the same economy; and if each of the small lamps had a sufficiently high resistance so that the cost of the conductors would not be excessive, I should say that that would be regarded as accomplishing the problem of subdivision; but so far as I know, lamps of this character had not been made prior to the date of the patent in suit, and in fact not until a considerable time after it was issued.

72 x-Q. When you say that lamps of "this character" had not been made prior to the date of the patent in suit, what do you mean by the words "of this character?"

A. I mean practically commercial incandescent lamps

each with an illuminating power of from six to ten times that of a gas-jet of which fifty could be operated in series.

73 x-Q. Do you hold the opinion that the invention described in the patent in suit is what constituted the practical solution of the problem of the subdivision of the electric light?

A. Yes.

74 x-Q. Is that, in your opinion, because the patent teaches how to construct a practically durable lamp which is capable of being made of an illuminating power about equal to that of a common gas-jet, and which is capable of being used either in series or in multiple arc according as the constructor of the particular lamps to be used may choose, or is it because the patent lays down rules for determining the size and proportions of the burner proper for a lamp to be used in muliple arc; or is it for both of these reasons combined?

A. In my opinion it is because the patent describes a method of making a practically commercial electric lamp with a burner possessing characteristics which permit a considerable number of such lamps to be operated in multiple-arc on a single circuit, which lamps the art without further instructions would know how to construct so that each should have an illuminating power equal to a gas jet and therefore adapted to interior lighting.

Adjourned for luncheon.

Resumed.

75 x-Q. Do you intend that to be an affirmative answer to any one of the three branches of the question, and if so to which?

A. No; it is a negative answer to all three branches of the question as they stand, and is an expression of my opinion concerning the reason why the invention described in the patent in suit constitutes the practical solution of the problem of subdivision, which I understand to be the purpose of the question.

76 x-Q. Then as I understand you, you hold that something more was necessary to the solution of the problem of the subdivision of the electric light than the construction of a practically durable lamp, which should be capable of being made of an illuminating power about equal to that of a common gas jet, and which should be capable of being used either in series or in multiple-arc as the constructor of the particular lamps to be used might choose. What more than this in your opinion was necessary?

A. No; that does not correctly express my views. When the method of making a practical incandescent lamp capable of use in considerable numbers in multiple-arc was described in the patent in suit, I think the art would have known how to make similar lamps of a power equal to a gas jet and that the problem of subdivision was accomplished.

77 x-Q. I do not from this answer understand what you consider to have been necessary to the practical solution of the problem of the subdivision of the electric light beyond what I have specified in my last question. Please be explicit on this point?

A. Referring to the exact language of 76 x-Q. I would say that in addition, the lamps should be capable of being used in considerable numbers in multiple-arc in order to solve the problem of subdivision; but in my opinion it was not at all necessary that the lamps should be capable of modification so that they could be used in series, although it happens that the form of lamp construction described in the patent permits this to be done.

78 x-Q. Suppose that all which Mr. Edison ever did in the matter of electric lighting had been to make, by the process described in the patent in suit and by the means known to the art at the date of his application for said patent, a half dozen incandescent lamps, and to have arranged said lamps in multiple-arc on a single circuit, and by experiment to have shown them to be

practically durable lamps, and then to have described to the world the process by which said lamps were made; would that in your opinion have been a solution of the problem of the subdivision of the electric light?

A. I think that that would have been a solution of the problem of subdivision and would have been so considered by the art after it had been proved that the lamps were durable, because the way in which to make such lamps of a power equal to a gas jet and the practicability of operating a considerable number of them on a single circuit in multiple-arc would have been at once recognized.

79 x-Q. Suppose he had not published to the world any description of the process of making these six lamps, would the actual making of the lamps and the testing of them as supposed in the last question have been a practical solution of the problem stated?

> Objected to as immaterial and as not warranted by the facts.

A. I think that this would have constituted a solution of the problem of subdivision.

Adjourned to Tuesday, August 5, 1890, at 11 A. M.

New York, August 5, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

Cross-examination of Mr. Clarke continued by General Duncan:

80 x-Q. Perhaps you observed that the hypothesis of my last two questions was not limited by the candle power of the six lamps. Did you notice that fact?

A. Yes, I did notice that, understanding that the lamps were to be made according to the process described in the patent in suit.

81 x-Q. Then the making and testing by Mr. Edison of six incandescent lamps of 100-candle power each—such lamps being made by the process described in the patent in suit and arranged for the test in multiple arc, even if he never had done anything more, would have been in your opinion a practical solution of the problem of the subdivision of the electric light, would it?

Objected to as immaterial and as not warranted by the facts as they appear on the record.

A. I think that it would practically have amounted to that, because Mr. Edison would then have been in possession of a simple, durable and economical lamp which could be operated in multiple arc with conductors of reasonable size and cost as compared with the total candle power obtained, and I think that he would at once have known without farther invention how to construct other similar lamps, each having the power of a gas jet which could be operated practically in considerable numbers in multiple arc, and which would have the other characteristics needful in practical commercial lamps. In short, for these reasons I think that Mr. Edison, after making and testing the six lamps in the manner mentioned in the question, would have at once recognized that he had solved the problem of subdivision, and I also think that the art would have recognized the problem as solved as soon as it was satisfied that the facts in possession of Mr. Edison were correct.

82 x-Q. These additional lamps which you say Mr. Edison would have been able "without invention" to construct would have required burners differing from those of the original six lamps, not only in extent of radiating surface but also in resistance would they not?

A. No, not unless we assume that the total amount of light furnished by the small lamps is to be the

same as that from the large lamps, and that in both cases they are to be operated under the same electromotive force with the same total amount of current and at the same economy, and that the size of the conductors in the two cases is also to be alike.

83 x-Q. Practically, do you think that Mr. Edison or any other person skilled in the art would have made the burners of the smaller lamps of the same size and proportions as those of the burners of the six original lamps?

A. Assuming that the six large lamps could be operated at a satisfactory degree of economy, I think that the natural course of proceedings in making the smaller lamps would, among other things, have been to reduce the radiating surface and increase the resistance of the burners.

84 x-Q. Do you wish to be understood as holding that other persons skilled in the art, as well as Mr. Edison, when advised of his mode of making the six large lamps referred to in 81 x-Q., and of his successful test of the same, would have known, without invention, how to change the size and proportions and resistance of the burner in order to produce durable and economical lamps of the smaller illuminating power of the ordinary gas jet?

A. Yes, I think that the art had the requisite knowledge, and would have at once applied it to the making of the smaller lamps, in view of the fact that it would be in possession of a practical incandescent lamp construction, and would know that the small and seemingly fragile burner was durable.

85 x-Q. Suppose that all which Mr. Edison had ever done in the matter of electric lighting had been to construct, by the process described in the patent in suit, with the employment of such means as were known to the art at the date of his application for such patent, fifty or a hundred incandescent lamps having carbon burners of the candle-power and resistance of those used in the so-called "municipal" lamps, manufactured and sold by the Edison Company, and on trial he had proved them to be durable lamps; would this, in your

opinion, have been a practical solution of the problem of the subdivision of the electric light?

Objected as immaterial and not warranted by the facts.

A. Yes, I think so, and I think that it would have been generally so considered after it had been proved and become generally known that the lamps were practically durable and economical, because I think that the art without further instruction or invention would have known how to construct similar lamps of the power of a gas-jet capable of being practically operated in multiple arc in considerable numbers on a single circuit.

86 x-Q. Would you make the same answer to the question, if the "municipal" lamps therein referred to had been of 100 candle-power each, instead of being from fifteen to thirty candle-power, which, as shown by Defendant's Exhibit "Complainant's List of Edison lamps," is the candle-power of this class of lamps as made by the Edison Company?

Same objection.

A. Yes, I do not see why the same answer is not entirely appropriate.

87 x-Q. In like manner, if the lamps referred to in 85 x-Q. had been lamps like those described under the heading "½ C. P. small lamps" of Defendant's Exhibit "Complainant's List of Edison lamps"; would this under the condition of said question have been, in your opinion, a practical solution of the problem of the subdivision of the electric light?

A. In my opinion it would, because I think that, for reasons already several times stated, the art would at once have known how to make similar lamps of the power of a gas jet, and also having the characteristic commercial advantages before mentioned. As I understand it, the patent in suit described a method of making a practically commercial incandescent electric

lamp, possessing characteristic features which enabled the art without additional instruction or invention to construct similar lamps of 16 candle-power, which could be operated in considerable numbers in multiple arc on a single circuit, and therefore adapted to interior lighting.

Adjourned for luncheon.

Resumed.

88 x-Q. In answering the last question did you have in mind the fact that the average resistance of the "½ C. P. small lamp" therein referred to is only about $3\frac{1}{10}$ ohms?

A. Yes. I think that the patent in suit describes a method of making a lamp capable of wide variations in resistance.

All of the foregoing answer after the first word objected to as irresponsive and irrelevant.

89 x-Q. Suppose the number of lamps named in the hypothesis contained in 85, 86, and 87 x-Qs., had been a half dozen instead of "fifty to one hundred;" would your answer to these questions as thus changed be substantially the same?

A. Yes, practically the same.

90 x-Q. Suppose that all Mr. Edison had ever done with electric lighting had been to make, by the process described in the patent in suit, with the employment of means known to the art at the date of his application for the said patent, a single lamp only, and on testing the same had proved it to be a durable lamp, would that in your opinion have been a practical solution of the problem of the subdivision of the electric light?

Objected to as immaterial and irrelevant.

A. Yes, and in general for the reasons given in my answer to the 85, 86 and 87 x-Qs.

91 x-Q. In so answering do you note the fact that my question contains no conditions as to the candle-power of the hypothetical lamp to which it relates?

Same objection.

A. Yes.

92 x-Q. Did you also take note of the fact that the question contains no condition as to the resistance, or the size, or the proportions of the burner of the hypothetical lamp to which it relates?

Same objection.

A. Yes.

93 x-Q. Assuming, then, that the illuminating power of the lamp had been 250 candles, and the resistance of the burner four ohms; would the making by Mr. Edison of a single lamp of that character, and the proving by him by actual tests that it was a practically durable lamp, have been a solution of the problem that we are talking about?

Same objection.

A. Assuming that such a lamp could be made according to the method described in the patent which would be a practically durable and economical lamp; I should say yes, for the reasons already stated which it does not seem necessary for me to repeat.

94 x-Q. Suppose Mr. Edison had made such a lamp, a single one only, by any other process than that described in the patent in suit (if that had been possible), and on trial such lamp had proved to be "durable and economical," and that had been all that he had done; would that, in your opinion, have been a practical solution of the problem we are talking about?

Same objection and as idefinite and uncertain in that it calls for an opinion upon a structure not described.

A. Not necessarily; not unless the character of the lamp and the method of its construction would have been sufficient to instruct the art, without the necessity of additional invention how to at once construct durable and economical lamps having the power of a gas-jet, which could be operated in considerable numbers in multiple arc on a single circuit, and altogether suited to interior lighting.

95 x-Q. In speaking of this matter of the subdivision of the electric light, you have frequently stated as one of the conditions of the solution of the problem that the lamp employed should be "economical;" what do you mean by that, as distinct from the matter of the prime cost of constructing the lamp, and from its durability?

A. As I understand it, the word "economy," in the sense in which it is stated in the question, refers to the actual amount of energy required to operate the lamps as compared with the amount of light obtained from them. Whenever I have referred to economy in the general sense, I have had in mind the total cost of keeping lamps in operation, for this is one of the important questions affecting subdivision commercially.

96 x-Q. In determining whether or not a given incandescent lamp is economical in the sense in which you say you have used this term, what has been your standard of comparison?

A. All other methods of interior lighting other than by incandescent lamps.

97 x-Q. How must the cost of incandescent lighting compare with these other methods of interior lighting before it would be economical, as you would understand that term in this connection?

A. From my point of view, this is a purely commercial question. I should say, that considering the price charged for lighting by the several methods and the advantages and disadvantages possessed by each, if the consumer preferred to use and pay for electric light at a price which would give a profit to the producer it would be because he considered it economical for his purposes at least, and I should say that under these circumstances the electric light would be properly called commercially economical.

98 x-Q. Then, as I understand you, you have used the term "economical," as applied to an incandescent lamp, to indicate simply that the lamp is one for which a commercial demand exits?

A. Yes, when I have used that term in a general sense, understanding as I do that no other lamp would be of any practical value.

Adjourned until August 6, 1890, at 11 A. M.

NEW YORK, August 6, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF MR. CLARKE BY GENERAL DUNCAN CONTINUED:

99 x-Q. Is that what you have meant when you have stated, as one of the conditions of the solution of the problem of the subdivision of the electric light, that the light must be economical?

A. Yes, or for which a demand could be created.

100 x-Q. Then in your suggestions heretofore, that the practical subdivision of the electric light required the production of a small incandescent lamp, which should also be economical, you did not intend, did you, to impose the condition that the aggregate light given off by a considerable number of lamps should be produced at the same cost as an equal amount of light developed at a single focus?

A. Yes, I did intend to impose that condition substantially; having in mind the fact that the cost of producing the electricity to supply the lamps is by far the greater part of the whole expense of keeping them in operation, understanding, as I do, that the *cost* referred to in the question is intended to cover only the cost of

producing the electricity to be supplied to incandescent lamps only.

101 x-Q. It is a fact, is it not, that with all the improvements of the present day it is much more expensive to produce a given amount of light with small incandescent lamps than with large arc lights?

A. By no means. Careful and accurate tests show that the difference in economy between arc and incandescent lamps is by no means so great as the public generally, and even scientific men, have in years past supposed. The popular idea that arc lights are very economical has, I think, arisen largely from the judgment formed by the intensely brilliant appearance of the focus from which the light emanates. Careful photometric tests have proved, however, that the popular idea of the power and economy of arc lights is entirely erroneous, and that under most favorable conditions they produce only three times the total amount of light which is produced by incandescent lamps with the same amount of power, and sometimes only one and one-half times as much light. In the commercial operation of such lamps the economy more often approaches the lower limit, as just stated, and does not on the average exceed twice the economy of incandescent lamps. The arc and incandescent lamps are economically applicable each to a special field of lighting, and although the arc lamp does produce light more economically than the incandescent lamp, the impossibility of usefully applying any considerable portion of all the light produced to interior lighting, would make it far less economical for this purpose than lighting by incandescent lamps.

102 x-Q. How is it as to the amount of light per horse power produced respectively by large incandescent lamps—say lamps of 100-candle power—and small incandescent lamps—say lamps of 16-candle power?

A. The total number of candles of light produced per horse power is practically the same in the two cases.

103 x-Q. In fact, is not the amount of light per horse-power produced by the later incandescent electric

light plants of the Edison Company much greater than that produced by that company in the years 1880 and 1881?

A. In 1880 and 1881 the total number of candles of light produced per horse-power was about sixty per cent. of what is produced by the lamps now manufactured by the Edison Company. Or, in other words, a horse-power now will operate fifteen 16-candle power lamps, whereas formerly it would operate from eight to nine.

Adjourned for luncheon.

Resumed.

104 x-Q. Is this improvement in the economy of operating the Edison lamp the result of changes made in the construction of the lamp itself, or is it due to other causes?

A. I do not think that it is due to any changes in the lamp construction, but to other causes.

105 x-Q. What other causes?

A. I do not think that I am sufficiently well acquainted with the processes now pursued in the manufacture of lamps, not considering myself skilled in the art of to-day in this regard, to explain the nature of the causes which have led to this increase in economy. I can, however, say in general that the burners made now are more durable than they formerly were, thus making it feasible to operate them at a higher temperature and incandescence, with a resulting gain in economy.

106 x-Q. Is not this increase of economy in the working of Edison incandescent lamp plants of which you speak the result in part also of improvements in the apparatus for generating the current, and in the means and method employed for distributing the current to the lamps?

A. Yes, to some extent.

107 x-Q. Is it not also true that the economy in running an electric light plant, including the cost of renewals of lamps, depends to a very considerable extent upon the electro-motive force of the current used?

A. Not if the lamps are operated at approximately the electro-motive force for which they were intended.

108 x-Q. Is it not a fact that a change in the electro-motive force of the current used with a given plant will work a corresponding change in the life of the lamps, and in the cost of maintaining the plant?

A. If the electro-motive force varies from the normal amount for which the lamps were intended, it will result in a change in the life of the lamps and in the economy with which the light is produced, but the economy does not necessarily vary directly as the electro-motive force; for example, where power can be obtained very cheaply the economy may be increased by reducing the electro-motive force, resulting in an increase in the life of the lamps and diminished expense for renewals; on the other hand, when power is expensive the best economy may be obtained by increasing the electro-motive force. In this latter case the expense of lamp renewals would be increased, but more light would be obtained for the power consumed, which would also result in a gain in economy.

Adjourned to Thursday, August 7th, at 11 A. M.

Met pursuant to adjournment.
Present—Counsel as before.

Cross-examination of Mr. Clarke by General Duncan continued:

109 x-Q. In answering 107 x-Q., you say that economy in running electric light plants does not depend to a very considerable extent upon the electro-motive force of the current used if the lamps are operated at approximately "the electro-motive force for which they were intended." Is it not a fact that practically it is necessary to organize incandescent lamps with special

reference to the character of the current with which they are to be used, and that the construction of incandescent lamps will vary with the varying conditions of the current by which they are run ?

A. It is a fact that it is desirable that the resistance of the lamps should be as great as is consistent with the possibility of making them practically durable in order that the cost of conductors and the interest on the same which enters as an element in the cost of operating the lamps may be low. Increase in the resistance of the lamps to attain this end results also in an increase in the electro-motive force and diminution in the amount of current required. Although the art has been able by the experience which it has gained since modern incandescent lighting began, to increase the resistance of lamps, resulting in the necessity of using less current and a higher electro-motive force, with a consequent saving in cost of conductors and reduction in the amount of interest chargeable to operating expenses, the increase in economy resulting from this has not been one of vital importance, and, I think, does not detract from the commercial value which the modern incandescent lamp has always had from the start. Of course in considering the commercial value of a system of incandescent lighting it is necessary to take into account the cost of the conductors. In answering 107 x-Q., however, I understood that the "economy in running an electric light plant, including the cost of renewals of lamps," was intended to refer to only three items, namely: the actual cost of producing the electricity plus the cost of renewing the lamps, said lamps being those which have been in general use since the date of the patent in suit.

Q. 110 x-Q. Why are certain lamps designated as "16-candle lamps" and others as "100-candle lamps," etc., the fact being, as I understand it, that any of these lamps can be run so as to develop either a higher or a lower candle-power than that indicated by their respective trade names ?

Adjourned for luncheon.

Resumed.

A. Lamps are designated as being of 16 candle-power or of 100 candle-power because the manufacturer intends that they shall be operated under conditions which will cause them to produce this amount of light at the best economy. The conditions under which they are to be operated, and the candle-power and economy to be obtained are questions which are predetermined by the manufacturer who constructs the lamps in such a manner that when operated under the conditions and at the candle-power intended they will require the same amount of power per candle irrespective of the total candle-power of the individual lamps; that is to say, when the 100 candle lamp is operated at its normal incandescence it will require $6\frac{1}{4}$ times the amount of power required to operate the 16-candle lamp. It is not a fact that any of these lamps can be practically operated at a higher or lower candle power than that indicated by their trade names excepting within very narrow limits and to a very limited extent occasionally resulting from conditions given in my answer to 108 x-Q. These conditions, however, do not often exist, and I think that the above statement is in general true. It might be inferred from the question that 16-candle lamps could be practically operated at say thirty-two or fifty or one hundred candles, or that the 100-candle lamp could be practically operated at fifty or at sixteen candles. In the first case the life of the lamps would be so short, and in the second case the amount of power required compared with the light obtained would be so great as to prevent the possibility of commercial operating lamps under such circumstances.

111 x-Q. I call your attention to an article published in the Electrician of January 31, 1885, on page 246 and signed Foussat, giving an account of certain tests made with Edison 16-candle lamps at the Edison factory in France; also to the article on Glow Lamps by Wilhelm Siemens, published in The Telegraphic Journal and Electrical Review, of

December 19, 1885, at pages 514 to 516, and continued on pages 531 to 533. Please state whether the facts therein set forth with reference to the various tests made with the Edison lamp do not show that it is entirely feasible to operate the Edison 16-candle lamps with either a higher or a lower electro-motive force than that which is required to produce in each lamp a light of sixteen candles. I call you attention especially to Table III. A. and Table IV. and Table V. of the Siemens' article, in which it appears that by increasing the electro-motive force of the current from ninety-six volts up to one hundred, to one hundred and fifteen and one hundred and twenty-three volts, in the successive tests, the candle power appears to have gone up respectively to 24 $\frac{25}{100}$, 44 $\frac{2}{10}$ and 68 $\frac{4}{10}$ candles ?

A. No, I don't think that either of the articles in question proves the feasibility of operating the lamps at a higher or lower electro-motive force than that for which they are intended, excepting within the limit of the small variations which are generally inseparable from the practical operation of electric light plants. The short account of the life of incandescent lamps at different electro-motive forces given by Foussat affords no information concerning the candle power or economy of the lamps, which, among other things, it would be absolutely necessary to know, as well as their durability, before it could be ascertained whether there was any commercial gain in changing the electro-motive force from its normal amount. Foussat himself makes no statement concerning the commercial advantage or disadvantage of so doing. As far as the article by Siemens proves anything concerning the relation between the electro-motive force and the commercial value of incandescent lamps, I think that it goes strongly towards proving that a great disadvantage results from operating the lamps at an electro-motive force greater than the normal. The normal electro-motive force of the lamps which Siemens tested was assumed as being ninety-six volts, but they gave a slightly better result economically speaking when tested at one hundred volts than they did when tested at ninety-six volts. The number of lamps used in each test however was limited to ten, which was altogether too small a number to conclusively prove the advantage of using the higher electro-motive force. Such a test in order to be satisfactory should be made upon a great many lamps in order to prevent defects in individual lamps from producing an error in the average result which would be almost certain to occur in testing only a few lamps.

Assuming, however, that the results of these two tests made by Siemens correctly represent what would have been obtained with a large number of lamps, then I should not say that there was an advantage in operating the lamps at a higher electro-motive force than that for which they were intended, but that, having regard to the best economy, they had been classified at too low an electro-motive force and candle-power. But because a manufacturer, according to his tests and standards of comparison and ideas as to what constitutes the best economy, sees fit to classify his lamps as being best suited to a certain candle-power and electro-motive force, and because some one afterwards ascertains that they will be a little more economicial if operated with a slightly different candle-power and electro-motive force, I do not think that that at all disproves the general proposition that from a commercial standpoint the electro-motive force and candle-power at which the lamps should be run in order to give the best economy as stated by the manufacturer is substantially correct.

Adjourned to August 8th, 1890, at 11 A. M.

NEW YORK, August 8, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF MR. CLARKE BY GENERAL DUNCAN CONTINUED:

(Answer to 111 x-Q. continued):

Although it will be true, as I have already stated, that some plants can be operated most economically by running the lamps at a slightly greater electro-motive force and candle-power than that designated by the manufacturer, while in other cases the best results with the same lamps will be obtained at a lower electro-motive force and candle-power, I think that the best average economy in a large number of plants will be obtained when the *average* electro-motive force and candle-power are about equal to that for which they were intended. The unreliability of the tests of a small number of lamps which were made at 96 and 100 volts as a basis upon which to form an opinion concerning the best economy is well illustrated by the fact that at the end of 800 hours, 3 lamps out of a total of 10, were broken in the test at 96 volts, while only one lamp out of 10 was broken in the same time in the test at 100 volts. The inference from this must be that when lamps are operated at the higher electro-motive force they will be more durable, which is absurd in view of the fact that we know that the average life of lamps is very greatly prolonged when operated at a lower electro-motive force. The table given by Foussat, above referred to, shows that lamps operated at 96 volts should have a life two and three-fourths times greater than when operated at 100 volts, a result directly contrary to that obtained by Siemens. To my mind these two tests cannot be relied upon as going to prove that a gain in economy may be obtained by operating lamps at a higher or lower electro-motive force than the normal. Tables IV. and V. illustrate not the economy but the great evil resulting from operating lamps at an electro-motive force very much greater than that for which they were intended. When 96 volt lamps were operated at 115 volts, 4 lamps out of 10 broke in 100 hours and at 123 volts no lamp lasted over 13 hours, a result which is in no sense commercial.

Defendants' counsel offers in evidence the articles referred to in the foregoing question and answer and the same are marked respectively "Defendants' Exhibit Foussat Article on Incandescent Lamps," and "Defendants' Exhibit Siemens' Article on Glow Lamps."

It is stipulated between counsel that the aforesaid articles were published at the dates and in the manner indicated in said question and that copies of said articles may be used instead of the original publications.

112 x-Q. How is the electro-motive force at which any given lamp should be run determined?

A. The resistance of the filament is made as high and the amount of its surface as low as is consistent with sufficient durability, at the same time having in mind the production of the required amount of light with the least practicable expenditure of power, all of which have to be considered together in making a lamp which shall have the best obtainable commercial efficiency. The electro-motive force at which the lamp should be run is determined by measuring the amount required to operate it when producing its normal amount of light.

113 x-Q. I call your attention to a passage found on page 316 of Maier's work "Arc and Glow Lamps," published in London, in 1886, as follows:

> "The glow lamps may, therefore, be distinguished according to the form of the filament; lamps with a long and thin filament and correspondingly high E. M. F., and lamps with a short and thick filament and correspondingly large current.

A characteristic difference between the two kinds of lamps, lies in the difference of cross section, whose size decreases with the increase of E. M. F. There can be no doubt that, *cæteris paribus*, a larger diameter constitutes a considerable advantage, namely, greater solidity of the carbon and longer life of the lamp.

All the considerations which ought to guide us in the choice of the raw material for the preparation of the filament, and which have been stated on page 302 apply with equal force to the question of length and cross-section. A thicker carbon thread will be more capable of resisting the shocks and concussions, as well as the high temperature to which it is in turn exposed, than a thin one; and this latter circumstance is of importance, not only from an economical but also from an æsthetical point of view, because the more intense the heating of the filament, the whiter is the light obtained.

It therefore follows that lamps of low tension present the advantage over lamps of high E. M. F., that for a definite illuminating power, their filaments are thicker and their durability and heating capacity correspondingly greater."

Do you agree with the statements contained in that passage?

A. While it is true, I believe that there is a slight increase in the durability of lamps with thicker filaments which have a lower resistance and require less electro-motive force and more current to operate them, the difference is not, I think, so marked as to result in such lamps having as high a commercial value as the lamps with thinner filaments. I think that Maier himself is also of the same opinion, for after saying as quoted in that question:

" It therefore follows that lamps of low tension " present the advantage over lamps of high E. M. " F. (electro-motive force), that for a definite il- " luminating power their filaments are thicker and

" their durability and heating capacity correspond- " ingly greater,"

he goes on to say:

" Against this one advantage of lamps of large current we must, however, put the serious drawback of the expensiveness of the leads (meaning conductors) * * *. This, of course, applies to parallel connection (meaning multiple-arc), which seems to be the most rational method for incandescent lighting. * * * From $d=c$ it will be seen how unfavorable the conditions are for lamps of large current, because a current of double strength requires four times the quantity of wire. * * * The drawback of expensiveness connected with the employment of lamps of low tension can be partly overcome by having recourse to certain combinations of parallel and series connection (multiple series or compound parallel), and we often find such like arrangements with lamps of large current, even with the Swan lamps. Two or more Swan lamps, for instance, are joined in series, and are arranged in parallel with a number of other lamps singularly connected; or the installation is made to consist of two or three large groups joined in series, each of which groups consists of an equal number of lamps arranged in parallel. The former arrangement has the disadvantage, that the extinction of one lamp brings about the extinction of those lamps which are contained in the same series. In case of the latter arrangement (although the extinction of one lamp is not accompanied by that of the others), we have to take into consideration that it is the same current which flows through the individual groups, each of which must be in a position to dispose of this current; now, on the extinction of several lamps, the current would be divided over a smaller number of lamps, and these lamps would be overworked.

An arrangement of this kind would be open to objections unless the lamp of each group were of a certain number, and unless the installation comprised several circuits independent of one another. It can only work successfully where all the lamps in circuit burn at the same time (it works very well at the Savoy Theatre, for instance), but it is not admissable where an individual burning of single lamps is required, and where a smaller or larger number of lamps have to be switched on or off, as the case may require: and still less so (even if all the lamps burn simultaneously) where lamps of different illuminating power, and consequently of different current strength are employed. * * *

We have now to decide the question as to the most convenient E. M. F. to be given to a system of lamps comprising the most varied types. This E. M. F. will be chosen as high as possible. If we assume again equal material and equal temperature of the filament, a surface of definite dimensions will correspond to an illuminating power, say of 10 candles (lamps of lower candle power will hardly be required for domestic purposes). If we now have a carbon of the smallest possible diameter consistent with the requirements of durability, we shall have to make it of sufficient length to obtain a surface corresponding to an illuminating power of 10 candles. That current having a sufficiently high E. M. F. to bring up the illuminating power of the lamp containing a filament of the said kind to 10 candles will be the desired current. The size of the lamp will be dependent in the first instance on the illuminating power, to be apportioned to the smallest type of the system, and secondly on the limit to which the diameter of the filament can be reduced, without injuring its durability."

I think that the extracts which I have quoted from Maier's book indicate that the author was of the opinion that lamps would have their greatest practical commercial value if the filaments were made as small in

diameter as possible consistent with sufficient durability and that the best commercial results were not to be sought for by increasing their diameter.

114 x-Q. To be more specific, I call your attention to the following sentence found in my quotation from Maier in my last question, to wit: "A thicker carbon " thread will be more capable of resisting the shocks and " concussions as well as the high temperature to which " it is in turn exposed than a thin one; and this latter " circumstance is of importance not only from an " economical but also from an æsthetical point of view, " because the more intense the heating of the filament, " the whiter is the light obtained;" and ask you whether that particular statement is true.

A. One would naturally suppose that this would be the case and I believe that such is the fact, but I do not understand that the difference in the ability of the thin carbon filaments of 16-candle-power 106-volt-lamps, and the thicker filaments of 16-candle-power 61-volt-lamps to resist shocks and concussions and the high temperature to which they are in practice subjected is so great as to result in a very marked difference in their durability.

115 x-Q. Assuming that you have referred in your last answer to two classes of lamps named in Defendant's Exhibit "Complainant's list of Edison Lamps;" please state what is the relative temperature at which those lamps are operated?

A. The data given in the Exhibit referred to would indicate that the filaments of 61-volt lamps are operated at a somewhat lower temperature than the 106-volt lamps, because the surface of the former is somewhat greater than that of the latter

Adjourned for luncheon.

Resumed.

Answer to 115 x-Q. continued.
according to the dimension of the filaments given in the tables. As a matter of fact, however, the amount of

surface in each one of the two lamps in question is as nearly the same as can be obtained in the practical construction of lamps. In practice also, although the two lamps are operated at different electro-motive forces each gves out practically the same amount of light and requires the same amount of power, and they are operated at the same temperature. The fact that the surfaces of the two lamps as figured from the dimensions of the filaments given in the tables differ in amount, I can only account for on the assumption that either the dimensions are incorrectly given therein, or are mere approximations to the actual truth.

116 x-Q. From your last answer it it evident that you deem the descriptions of the Edison lamps contained in "Complainants list of Edison lamps" to be incorrect and unreliable, notwithstanding the fact that this list was furnished by the counsel of the Edison Company as correctly representing said Company's lamps; can you now give what you would regard as the correct figures for the two classes of lamps to which you have been referring, to wit, the "16-candle-power new lamps," and the "16-candle-power B new lamps;" also please point out the other misstatements in said list if such exist?

Question objected to as containing an assumption unwarranted by the statements of the witness.

A. Thus far I have seen no reason which leads me to think that the statements made in the exhibit referred to concerning the candle-power, volts (electro-motive force) and ohms (resistance) are not substantially correct. I have doubts, however, of the *absolute* correctness of the dimensions of the filaments which have been given and which it would be necessary to know in order to *accurately* compare the relative temperatures at which they are operated, because I find that the surfaces of two different filaments, according to the dimensions given, are somewhat different, whereas they should be alike. I see no reason, however, for assuming that these dimensions as given are not sufficiently accurate to give an approximately correct idea of the size of the filaments. As to the "16 candle-power new lamps" and the "16 candle-power B new lamps," specifically referred to in the question, the data concerning them appears to be correct, excepting as to the absolute correctness of the dimensions of the filament. I am unable to state what the correct dimensions are excepting to say that I understand that they are such as will make the surfaces of the two filaments the same. At this moment I do not perceive any other inaccuracies.

117 x-Q. As given in the table referred to, what is the difference in the external dimensions or radiating surface of these two filaments?

A. The radiating surface of the 61-volt lamp is 16 per cent. greater than that of the 106-volt lamp according to the dimensions given in the table.

118 x-Q. How does the illuminating power of the carbon conductor of an electric lamp change with changes in the temperature?

A. The illuminating power increases and diminishes with an increase or diminution in temperature.

119 x-Q. What is the *ratio* between the increase of light and the increase of heat?

A. The illuminating power increases in a very much more rapid ratio than the increase in the heat developed in the burner.

Adjourned to August 9th, 1890, at 11 A. M.

New York, August 9, 1890.

Met pursuant to adjournment.

Present--Counsel as before.

Cross-examination of Mr. Clarke by General Duncan continued:

Answer to 119 x-Q. continued:

The exact ratio can only be expressed by a complicated mathematical formula. With a lamp whose normal power is 16 candles, the illuminating power between five and twenty candles increasing approximately as the cube of the amount of heat developed in the burner.

120 x-Q. About when was the Edison "16-candle power new lamp" substituted for the "16-candle power old lamp"?

A. I think it was about two or three years ago.

121 x-Q. What are the relative amounts of light per horse-power developed in the Edison "16-candle power old lamp" and the Edison "16-candle power new lamp" when run with what you call their normal currents?

A. The new lamps produce about 60 per cent. more light per horse-power than the old lamps.

122 x-Q. How do the temperatures of the carbons of these two lamps compare?

A. The temperature of the carbon of the old lamp is considerably lower than that of the carbon in the new lamp when both are operated at 16-candle power.

123 x-Q. If the old lamp had been run at the same temperature at which the new lamp is run, how much light would it have given? I assume that the dimensions of the burners of these lamps as given in the list of Edison lamps furnished by complainants counsel are correct?

A. It would have given about 32 candles of light, or double its normal amount.

124 x-Q. If run at that higher temperature would the old lamp have given the same amount of candles per horse-power as the new lamps give?

A. Yes, approximately.

125 x-Q. Would not the old lamps then have been more economical when run at this higher temperature, using the word economical in its technical sense, that is, as having relation to the ratio of light produced to the power consumed?

A. Yes, it would have had approximately the same economy as the new lamp.

126 x-Q. Can you explain why the old lamp was not run at this higher temperature?

A. I suppose for the reason that where the lamps were operated at the lower temperature the expense of renewing the lamps plus the cost of supplying them with the necessary power would be reduced to a minimum and the best commercial results would be thus obtained, and also because the lamp when run at the higher temperature at which they would be of 32-candle power would not be adapted to general interior lighting.

Of course similar lamps which would be of 16-candle power, when operated at the higher temperature could be constructed, but they would have the same disadvantage as the 32-candle lamps because of their short life.

127 x-Q. In view of the fact that the carbon of the old lamp was of nearly 2½ times the cross-section of that of the new lamp, how do you account for the fact, which evidently you have assumed in your last answer, that it would not be possible to run the thicker carbon at a higher temperature than the thinner one without reducing the life of the former below that of the latter?

A. In my answer I assumed that the thick and the thin carbons were both made with the skill which had been required by the art at the time the old lamps were being made. If both of these carbons are run at the same temperature they will, I think, have approximately the same durability with perhaps a very slight advantage in favor of the thicker carbon, but not a difference sufficiently great to cause a practical difference in their commercial efficiency. Since the time when old lamps were manufactured the art has acquired skill and experience, and it has become possible to make small carbons such as are used in new lamps which have about the same durability as the large carbons of the old lamps, although the new carbons are run at a higher temperature.

Adjourned for luncheon.

Resumed.

128 x-Q. Is it not a fact that a thin carbon will wear out sooner than a thicker carbon which has been made of the same material, and by the same process and with the same skill, if the two are operated at the same temperature?

A. I do not know that any such thing as the *wearing out* of a carbon burner is recognized by the art as having any bearing upon the question of the durability of electric lamps, understanding as I do that the question asks whether there is not a wasting away of the burner which reduces its diameter and eventually leads to its failure. No rational explanation of the reason why carbon filaments break after being in use a certain number of hours has, so far as I know, ever yet been profounded. All that we know concerning this matter is that eventually they do break, and that if made by one process and out of one material they will, on the average, break sooner than if made by some other process or some other material. After lamps have been in prolonged use and have failed, no alteration in their size is perceptible such as to warrant the assumption that whatever wasting away occurs, if there be any, could have been the cause of their breaking.

129 x-Q. I suppose you are familar with the paper read by John W. Howell, the electrician of the Edison Lamp Company, before the American Institute of Electrical Engineers in April, 1888, on "The Maximum Efficiency of Incandescent Lamps," and with the discussion had by the Institute on that paper?

A. I have read the paper, but do not now remember the contents of the same in detail.

130 x-Q. Do you regard Mr. Howell as an authority on the matters of which that paper treats?

A. I should consider him to be an authority on the efficiency of incandescent lamps, which is the title of his article.

131 x-Q. Also reliable in his statements of fact?

A. I have always considered him to be reliable.

132 x-Q. In the discussion following the reading of his paper, as reported on page 254 of the transactions of the Institute, Mr. Howell said, referring to the use of incandescent lamps:

> "In practice you find it universal almost that lamps are taken down before they break. Of course, that affects directly the cost of the lamps, because a central station, furnishing lamps for nothing, gives a man a lamp when it breaks, and also when a lamp becomes so black that you have to put a new one in."

First. Do you understand that this statement of Mr. Howell, that incandescent lamps are generally taken down before they break, is true?

A. I think that it is true for central stations, but I believe that in case of isolated plants, where the lamps are purchased by the user, they are not replaced until they break.

133 x-Q. Why as a rule are central station lamps renewed before they break?

A. I believe it is because the company agrees to furnish the customer with a given amount of light at a stated price from lamps which the Company provides. In time the amount of light given out by the lamp diminishes and before this takes place to too great degree new lamps must be provided in order that the customer shall continue to receive the amount of light for which he is paying.

134 x-Q. Is this same diminution in the light-giving power of the lamp observable when the lamp is used in an isolated plant?

A. Yes, but since the cost of lamps to isolated plants is much greater than the price for which they are supplied to central stations there is an advantage gained in the former case in using them until they break.

135 x-Q. I suppose that you are familiar with the results of the tests of incandescent lamps made by a committee of scientific gentlemen selected by the Franklin Institute in 1885, are you not?

A. I was at one time, but fear that I have forgotten some of them.

136 x-Q. Is it not established by those tests made under the auspices of the Franklin Institute, as also by the various tests which are reported by Siemens in defendants' exhibit "Siemens Article," and is it not a fact of which you are cognizant otherwise, that an incandescent lamp begins to lose efficiency, that is, begins to fall off in illuminating power, with a current of a given electro-motive force, very soon after it is put in circuit, and that this decrease in efficiency continues gradually, becoming greater and greater, until the loss of illuminating power becomes so great that a new lamp must be substituted, or until the lamp fails by breakage of the carbon?

A. Yes, such is the case.

137 x-Q. Is it also a fact that this falling off in illuminating power is accompanied by a marked increase in the resistance of the burner?

A. I believe that the lamps increase in resistance about seven per cent.

138 x-Q. What was the aggregate falling off in illuminating power of the Edison lamps in the Franklin Institute tests?

A. After the lamps had been burning one thousand and six hours when the test practically terminated, there was a falling off in candle power, from what it was at the beginning of the test of about thirty-five per cent.

Adjourned to August 11, 1890, at 11 A. M.

New York, August 11, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

Cross-examination of Mr. Clarke by General Duncan, continued:

139 x-Q. It is a fact, is it not, that incandescent lamps blacken more or less with use?

A. Yes, but not to such an extent as to generally result in their ceasing to be of commercial utility on this account.

140 x-Q. Then what did Mr. Howell mean by saying, as in the passage quoted in 132 x-Q., that "a central "station * * * gives a man a lamp when it breaks, "and also when a lamp becomes so black that you "have to put a new one in?"

A. It is to be noted that Mr. Howell also said "in practice you find it universal almost that the lamps are taken down before they break, * * *" and that all of his remarks are limited to lamps supplied from a central station. I was under the impression when answering 132 x-Q., that in central station lighting the use of the new lamps having great durability (although run at a higher temperature than the old lamps) had resulted in the necessity of their renewal more generally on account of reduction in efficiency from the darkening of the globe and other causes than on account of the rupture of the burners. My impression was also apparently confirmed by the statements made by Mr. Howell, I find, however, judging from the results which are obtained in central station lighting in New York, that the impression which I had gained was a somewhat exaggerated one and that, since using the new lamps, it has been found that from forty to fifty per cent. have to be renewed in central station lighting because of a reduction in efficiency and the darkening of the globes. With the old lamps, operated at a lower temperature, which were in use up to about two or three years ago, not more than fifteen per cent. of the total number had to be renewed on this account. When we take into account the fact that by far the greater number of all the lamps in isolated plants remain in use until they break and that the number of lamps in such plants is a large per cent. of the total number in use, it will, I think, be obvious that by far the greater number of all the lamps are replaced because they break and not because of a reduction in efficiency and darkening of the globes.

141 x-Q. What causes this darkening of the globe of an incandescent lamp?

A. I suppose that it is caused by a deposit of carbon, or some compounds of carbon and other substances coming from the burner.

142 x-Q. What is it that causes an increase in the resistance of the burner as its use is continued?

A. I think that it is considered in the main to be due to a diminution in the mass of carbon in the burner which takes place very slowly during the operation of the lamp.

143 x-Q. On page 271 of Maier's work on Arc and Glow Lamps, in speaking of the lamps of King, Lodyguine, Kosloff, Konn and Sawyer, Maier says:

> "In all these lamps, although the carbon does not burn, in the true sense of the word, there is yet a sort of disintegration or evaporation, which gradually destroys the incandescent carbon. This evaporation is moreover clearly proved by a deposit of sublimated carbon, in the form of a very fine powder on the interior surface of the globes, and the different interior parts of the apparatus."

It is not a fact that in the modern incandescent commercial lamps this same operation which Maier ascribes to the old lamps takes place, although in a less degree?

A. No, not as Maier states it. In the first place the author says that the carbon does not burn in the true sense of the word. Even the densest carbon is very porous and will hold confined within its pores a large amount of air, which, if allowed to remain, will cause the carbon to burn *in the true sense of the word* to some extent. The King, Lodyguine, Kosloff and Konn lamps all had this defect, and in the Lodyguine, Kosloff, Konn and Sawyer lamps, *true combustion* took place on account of the defective construction of the lamp chambers, which permitted the oxygen of the air to enter.

Adjourned for luncheon.

Resumed.

Answer to 143 x-Q. continued.

In addition to combustion a rapid evaporation of the carbons also took place because of the large amount of gas which the lamp chambers and burners contained. From both of these causes it resulted that none of these lamps had a long enough life to make them of any practical value, although the burners were made quite thick so as to endure these destructive actions as long as possible. The thin filaments of modern incandescent lamps cannot be destroyed by combustion, because all oxygen is removed from the burner and the lamp chamber, neither are they subject to an evaporation which has any effect in causing them to break, for the reason that the globe is exhausted of all gas to an exceedingly high degree. This is entirely contrary to the experience had with the old lamps before mentioned, in which the evaporation took place very rapidly and to which Maier on pages 263 and 264 of his book, referred to in the question, calls attention; the author says, speaking of Reynier's semi-incandescent lamp:

> "Reynier was led to the construction of his lamp by making experiments on incandescence with some Russian lamps" (obviously referring to the Lodyguine lamp and its modifications by Kosloff and Kohn) "which will be mentioned hereafter. All these lamps had one and the same serious defect the waste of the central part of the carbon which brought about its rupture, and necessitated the substitution of a fresh carbon."

Inasmuch as the slight evaporation of the filament which takes places in modern lamps does not cause the same to wear out or break, and does not otherwise prevent the lamps from having a useful life of many hundred hours, while on the contrary the evaporation of the carbon rods of the old lamps took place so rapidly that it was the immediate cause of their failure within a few hours, I think that the term evaporation as applied to old and to modern incandescent lamps has two entirely different meanings when we consider the commercial value of electric lamps. In the former case an evaporation takes place which destroyed the commercial value of the lamps, and in the latter case an evaporation takes place which does not prevent the lamps having a great commercial value for several hundred hours. The so-called evaporation which takes place in the the two cases may, I think, be well compared as to commercial results to the loss of spirits which takes place on account of a defective and leaky cask, when compared with the loss (termed evaporation) which occurs by leakage through the pores of the wood of a perfect cask.

144 x-Q. You say that the "evaporation of the filament which takes place in modern lamps does not cause the same to wear out or break." What then does cause the breakage or wearing out of the filament, assuming the lamp to be run at its normal incandescence?

A. I do not know what causes the final rupture of the filament, or that any one has as yet given any plausible explanation of the reason why it occurs. But all the facts in our possession point to the conclusion that it is not caused by evaporation.

Adjourned till August 12, 1890, at 11 A. M.

New York, Aug. 12, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

Cross-examination of Mr. Clarke by General Duncan continued:

145 x-Q. Of course, you do not wish to be understood that literally, as your words in answer to 143 x-Q. would seem to indicate, "*all* oxygen is removed from the burner and the lamp chamber" of the modern incandescent lamp?

A. Of course not. That I think would be a practi-

cal impossibility. I meant all that it was necessary to remove in order to prevent any practical injury resulting to the carbon burner on account of what oxygen might remain, that is, such an injury as would destroy the commercial value of the lamp.

146 x-Q. What becomes of the oxygen which is left in the globe of the modern lamp?

A. I think some of it remains adherent to the interior walls of the lamp chamber and within the platinum connecting wires and carbon clamps, but that by far the greater portion of it unites with the carbon filament. The total amount of oxygen, however, which is in the lamp is exceedingly small, and I believe has no effect whatever upon its commercial value.

147 x-Q. This union of the oxygen with the carbon burner is combustion, is it not?

A. Yes, but it takes places only to an exceedingly limited extent, and does not, as I understand it, impair the durability of the burner.

148 x-Q. And you also understand, do you not, that the disintegration of the carbon of the burner, to which the blackening of the globe is due, is not sufficient commercially to impair the durability of the burner.

A. Yes, understanding that durability refers to the rupture of the burner. The commercial life of a certain proportion of the lamps operated from central stations is limited by a reduction in efficiency and a blackening of the globe due to disintegration as I have already stated in answer to 140 x-Q.

149 x-Q. Is not the combustion which you admit goes on in the modern incandescent lamps just as real as that which you have said took place in the old lamps?

A. Yes, the combustion which occurs in the two cases is the same sort of a chemical operation but from a commercial point of view one is by no means *as real as* the other for the reason that the oxygen left in the burners and chambers of the old lamps or that which would leak in owing to defectve construction would have the effect of lessening the life of the lamps, whereas in modern lamps there is no leakage, and the oxygen left in the lamps does not, so far as I know, diminish their life.

150 x-Q. Is there any way of proving that this combustion in the modern lamp does not to some extent contribute to diminish the life and the efficiency of the lamp?

A. I think that there is good reason for assuming that it does result in a very minute reduction in the efficiency of the lamp because of a slight diminution in the mass of carbon and proportionate increase of resistence, but I do not believe that the reduction of efficiency from this cause is sufficiently great to have any practical effect on the commercial value of the lamp. I think that there is on the other hand a very good reason for assuming that the effect of this combustion, exceedingly small in amount, does not contribute to diminish the life of the lamp, because it will occur with an approximate uniformity over the entire surface of the burner, having the uniformity of its structure and strength unimpaired. If combustion did diminish the life of the burner it would be brought about by a preponderance of this action at some particular part of the filament which would result in a gradual diminution in its size and very perceptible increase in the brilliancy of the light and final rupture at that part. No such action, however, does take place in the practical operation of modern lamps. The burners remain, so far as can be perceived, practically uniform in size and brilliancy throughout their entire length and until the end of their life when, suddenly and for no known reason, they break at some place. So far as I know the place at which the rupture finally occurs cannot be predetermined by any known means.

151 x-Q. In your answer to question 12 you say that Professor Cross, in the opinion of his which you there criticise, did not make proper account of the disintegration of the carbons of the old lamps which preceded Edison's platinum lamp. Do you understand that it was the *thickness* of the carbons in these old lamps that was the cause of the disintegration of which you speak?

A. Understanding that the term disintegration in the question refers to the depositing of the carbon of the burner upon the globe and other parts of the lamp, it was, in my opinion, not due to the thickness of the burner, but the detrimental effect of this disintegration or evaporation was diminished by making the burner thick.

152 x-Q. To make the question more comprehensive, do you understand that the short life of the old lamps was due to the fact that the carbons were comparatively thick rather than thin?

Adjourned for luncheon.

A. With regard to the matter of disintegration and combustion, I answer, No. With respect to the difficulty of obtaining and preserving a durable contact between the carbon rod and leading-in wires, owing to the large amount of current required and the liability of the burner to fracture on account of its rigidity and inability to accommodate itself to the expansion and contraction which take place when it is heated and cooled, I answer, yes.

153 x-Q. I do not think that you have fairly answered my last question. I understand you to hold that the old lamps, which, it is claimed, had thick carbons, were failures because of their short life. I desire to know whether you consider that this failure was due to the fact that the carbons were made thick rather than thin. Another way of putting it would be this: If the carbons of those lamps had been made very much thinner, all the other conditions remaining the same, would that, in your opinion, have added materially to the life of the lamps?

A. Taking the last part of the question, beginning with the words, "If the carbons, etc," as being the sum and substance of the whole question, in my opinion the thin carbons would have had the shorter life.

154 x-Q. In like manner, comparing two modern com-

mercial lamps, having carbons of different cross-sections, as, for instance, one of the Edison "16-candle-power new lamps" with one of the Edison "20-C. P. Municipal new lamps," the former of which, according to "complainant's list of Edison lamps," has a cross-section only about one-twelfth that of the latter, do you understand that this difference in size of the burners makes any material difference in the life of the lamps?

A. Not any great difference, I think.

155 x-Q. How far do you consider that the superior durability of the modern incandescent lamp over the old carbon lamps, of date prior to 1879, depends upon the fact, if it be a fact, that the modern lamp uses a burner of smaller cross-section than the old lamp?

A. I think that the smaller cross-section which is given to the burners of modern lamps has the effect of making them more durable than the carbon rods of the old lamps would be under the same conditions, because they have more flexibility when they are small, and are therefore not so liable to rupture in expanding and contracting when held between rigid supports. They would also be more durable, for the reason that their points of contact with the leading-in wires would better withstand the effects of the smaller amount of current required.

Adjourned to August 14th, 1890, at 11 A. M.

New York, Aug. 14th, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

157 x-Q. You have referred in your testimony heretofore to the King and the Roberts lamps as having vacua not as high as those of the modern lamps; you do not understand, do you, that either King or Roberts deemed it a desirable thing to leave a portion of air in the globe of his lamp?

A. No, I think that they deemed it desirable to remove the air from the lamp chamber, but only for the purpose of preventing the oxygen of the air from consuming the carbon. In my opinion neither King nor Roberts describe an effectual method of doing this.

158 x-Q. Do you think that it would have involved invention, after the invention of the Sprengel pump, to have made use of this apparatus for exhausting the globe of a Roberts lamp and thereby securing a better vacuum than could have been obtained with the old piston air-pump, which presumably would have been used prior to the invention of the Sprengel pump?

A. I do not think that there would have been any invention in the employment of the Sprengel pump in place of the old piston pump for the purpose of exhausting the air from the globe of the Roberts lamp; I do not think, however, as is implied in the question, that any practically better vacuum would be obtained with the improved pump, because of the leakage of the air into the lamp chamber, which would take place on account of its defective construction.

159 x-Q. If, on using the improved apparatus for producing the higher vacuum, one had found the lamp globe so defective in construction as to permit air to leak in as rapidly as it was removed from the globe, would not such person, in your opinion, naturally have resorted to some modification of the construction, assuming such to have existed, which would have prevented this leakage?

A. Yes, I think that he would have attempted to diminish the leakage. In fact the history of the art showed that it was attempted and the impossibility of accomplishing it, with the separable lamp chambers which had to be used, led to the abandonment of attempts to use a vacuum and the substitution of a gas within the lamp chamber, at about atmospheric pressure, which would not burn the carbon and which it was hoped would prevent the ingress of air. For several years prior to the date of the patent in suit efforts to construct a practical incandescent carbon lamp were almost wholly confined to the use of a carbon burner in a separable chamber filled with such a gas, and it was, I think, generally considered by the art that lamps of this character held out the most promise of eventual success.

160 x-Q. In answer to Q. 12, you have assumed that Edison discovered certain new physical properties of carbon, and that because of such discovery the lamp which he devised—or, more indefinitely, some one of the many lamps devised by him—is entitled to rank as a great invention. Will you kindly indicate more fully what these alleged new physical properties of carbon are which you say Mr. Edison discovered.

A. In my opinion, Mr. Edison discovered that carbon when heated to incandescence in a vacuum, by the passage of an electric current through it, is stable, and that this is true even when the carbon is small in diameter and seemingly very fragile. As I understand it, this discovery which was made by Mr. Edison was entirely distinct from the instability which carbon would have in the presence of oxygen. It was, of course, known when attempts were first made to make incandescent carbon lamps that the oxygen of the air would consume the carbon, and in attempting to make durable lamps the efforts of the art were in the main directed towards keeping the oxygen away from the carbon, but it was well known that in addition to this difficulty a very rapid volatilization or, as we have termed it, evaporation took place, which soon resulted in the destruction of the burner. This evaporation was not understood to arise from the presence of oxygen or any other gas which might be in the lamp chamber, but was supposed to be due solely to the combined action of the electric current and the heat produced by it. And the art generally understood that this was a difficulty which could not be overcome by any means then known. In fact, when Edison's invention was first announced to the public, several scientific men hastened to pronounce the invention a failure because they believed that the carbon filament would have no durability on account of this destructive action of the heat and current, and ob-

viously for the reason that they did not know that there would be any virtue in the use of a high vacuum.

161 x-Q. It seems to me that your last answer proceeds upon a false assumption, viz., that the carbon of an Edison lamp is *stable*. I understand the fact to be, as abundantly established by the testimony in this case, that the carbon of an Edison lamp gradually deteriorates in efficiency, owing, in part at least, to the removal of particles which are carried over and deposited upon the glass and other adjacent parts, until at last it is unable longer to endure the stress of the current and goes to pieces. I also understand that the guaranteed life of an ordinary Edison lamp does not exceed 600 hours of service. In view of these facts, when you say that "Mr. Edison discovered that carbon when heated to incandescence in a vacuum by the passage of an electric current through it is stable," do you mean to assert anything more than this, viz., that he discovered by experiment that if carbon were enclosed in a better vacuum than had been used in the earlier incandescent lamps it would have a longer life when brought to incandescence, and that by making the vacuum sufficiently high it would be possible to give the carbon sufficient durability for commercial purposes?

Objected to as containing statements not warranted by the evidence.

A. The facts are that the lamp does gradually deteriorate in efficiency partly on account of evaporation of carbon and darkening of the globe, and that the carbon does finally break, unless removed from the circuit before this occurs, because of too great a reduction in efficiency and diminution of light. As I have before stated, however, if the lamp continues in use until broken the facts in our possession lead to the conclusion that it is not due to the evaporation of the carbon. It is also true I believe that the guaranteed life of the Edison lamps is 600 hours which we may take as a criterion of their durability. When I say that Edison discovered that carbon was stable in a high vacuum I did not mean that when used as the burner of an incandescent lamp it would last forever. I cannot now recall anything which is used in the arts which will meet this definition of stability. I believe it is generally understood as an abstract proposition that everything wears out. What I mean by stability, in the light of Edison's discovery, is this, that, prior to the date of the patent in suit, it was supposed that the carbon burner, under the influence of the heat and the current, was necessarily subject to a very rapid evaporation which would be the immediate cause of its destruction in a few hours, and that this rapid evaporation would take place no matter how much gas there might be in the lamp chamber so long as it did not contain oxygen which would burn the carbon. Mr. Edison, as I understand it, discovered that by removing the gas within the globe until a very high vacuum was obtained this rapid evaporation ceased and that the stability of the carbon became so great that he could make lamps with even thin burners which would endure for several hundred hours. Considered as a matter of common sense, and in its effect upon the commercial question of electric lighting, this certainly is, in my opinion, a discovery of the stability of carbon.

162 x-Q. After all, would not the correct statement of the matter be that Mr. Edison discovered by his experiments that with a very high vacuum the carbon would be more enduring than with the earlier comparitively low vacua, and sufficiently enduring to be of value commercially?

A. Yes, substantially that, bearing in mind that prior to the date of the patent in suit the art did not suppose that the amount of gas in the globe (that is to say, the condition of the vacuum) had anything to do with the question of evaporation and durability so long as it contained no oxygen.

Adjourned to August 15th, 1890, at 11 A. M.

New York, Aug. 15th, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

163 x-Q. Where, prior to the date of the patent in suit, do you find any statement to the effect that the amount of gas in the globe does not have anything to do with the question of evaporation or durability so long as it contains no oxygen?

A. I do not remember of the statement having been made in these exact words, but at the moment I recall three instances of statements made prior to the date of the patent in suit, which, in my opinion, are in every way the equivalent of it. Fontaine, in his book published in 1877, made the following statement, which I read from Higgs' translation:

> "The vacuum never being perfect in the receivers the first carbon is in greater part consumed. It would appear that consequently upon the little oxygen contained in the lamp being transformed into carbonic acid and carbonic oxide the carbon should be preserved indefinitely. But there is then produced a kind of evaporation which continues to slowly destroy the incandescent rods. This evaporation is besides clearly proved by a pulverent deposit of sublimed carbon that we have found on the interior surface of the bells on the several interior parts, rods, contracts, hammers, etc."

It appears obvious that Fontaine considered that this evaporation was a necessary evil, and that it was in no way due to the presence of the gas in the globe, for he practically says that inasmuch as the globe contained only an inert gas it would seem that the carbon *ought to be preserved indefinitely.*

Bernstein in his work on electric lighting, published in Berlin in 1880, in speaking of the old incandescent carbon lamp says:

> "The disadvantage of all these lamps lies in the

fact that the thin carbon pencil has only a very short life and soon breaks at the weakest point. It is likewise naturally obvious that the carbon pencil is very quickly consumed in the air. To remedy this evil, the carbon pencil has been enclosed in an air-tight glass bell, and later on this has been filled with gases which prevent combustion. But it appears that at a white heat the electric current causes small particles to be thrown off from the carbon pencils obtainable, and thus also in this case a pretty rapid wearing out takes place. At all events the results up to this time do not sound very encouraging."

Bernstein apparently did not ascribe this evaporation to the nature or amount of gas in the lamp chamber, but solely to the action of the current upon the white hot carbon. The preface of Bernstein's work is dated November, 1879, and inasmuch as the work contains no reference to Edison's carbon lamp it was obviously written without any knowledge of it. Prof. Morton, in his "Lecture upon the Electric Light," delivered October 17th, 1878, and published in the "American Gas Light Journal," January 2d, 1879, in speaking of the Sawyer-Man lamp, says:

> "This differs from the former apparatus (the author is referring to the old carbon lamps of Starr and Konn) in no important feature except that the interior of the vessel is said to be filled with pure nitrogen at the ordinary pressure. The carbon rods are said not to waste away in the lamps. Without knowing anything positive on the subject, my opinion is that this is only because they have not been subjected to strong currents, but have only been heated to the extent of yielding a light of one or two burners. Under these circumstances the carbons of the Konn lamp will last a long time, but, on the other hand, the light so obtained is not economical, as we see above."

In the light of the above quotation from Prof. Morton's lecture, I think that he was of the opinion that the amount of evaporation depended solely upon the degree of heat and strength of current, and in no way to the gas contained in the globe.

I think that these citations go to show the substantial correctness of the statement which I made in answer to 161 x-Q. to the effect that it was understood by the art that the rapid evaporation would take place, no matter how much gas there might be in the lamp chamber, so long as it did not contain oxygen which would burn the carbon.

164 x-Q. Assuming that the art understood that a rapid "evaporation" of the carbon would take place when the lamp chamber was filled with nitrogen, or with a carbonic oxide or carbonic acid gas, even though no oxygen were present, how does that justify the conclusion which I understand you draw from it, that the art also understood that this "evaporation" would continue to the same degree if these inert gases were removed by making the highest attainable vacuum?

A. I think that the conclusion is fully justified in view of the fact that, so far as I know, none of the scientists and writers upon the subject of incandescent lighting considered this evaporation to be in any way caused by the gases in the globe, but understood that it was due *solely* to the combined action of the high heat and the current. I do not see how the art could have been led to the conclusion that evaporation would be diminished by removing the gas which as far as this action is concerned was supposed to be harmless.

165 x-Q. Have you any warrant in the writings preceding the date of the patent in suit, other than the quotations made in your last answer but one, for this statement just made by you, and which seems to be the premise of your whole argument, that it was supposed by the art that the presence in the lamp globe of gases other than oxygen was harmless?

A. I do not at present recall any other articles, published prior to the date of the patent in suit, which deal with the question as completely as those to which I have referred. But as an additional confirmation of my opinion that it was held that these gases were harmless, or in other words that there was no virtue in the absence of these gases, I will refer to the skeptical spirit with which Edison's invention was first received by some scientists as is fully set forth in my answer to 13 Q.

166 x-Q. Where, in the writings which preceded the date of the patent in suit, other than the quotations made in answer to 163 x-Q., do you find warrant for your position that the art believed the rapid dissolution of the carbons of the incandescent lamps of that day was due to other causes than the presence in the lamp chamber of oxygen or, when that was removed as completely as possible, of the other gases used in effecting the expulsion of the oxygen?

A. I have not said that the art believed that dissolution of the carbon was due to other causes than the presence of oxygen in the chamber. The art always knew that oxygen would burn and destroy the carbon. Concerning the opinion, which I believe the art held, that the evaporation of the carbon was not due to the presence of other gases, in addition to the references given in my answer to 163 x-Q. I find a statement which I think is of similiar import in British Letters Patent No. 11076 granted to Greener & Staite in 1846, from which I quote as follows:

"Both carbon and platinum have been before employed as medio for the development and exhibition of electric light, but carbon even in the purest states in which it has hitherto been obtainable, when ignited, or rendered luminous in an air-tight glass vessel by means of electric currents has been found to give out various extraneous matters which interfere with the continuity of the light and which being precipitated on the inside of the glass vessel obscure and darken the same; and plain surfaced platinum when substituted for the carbon in the air tight vessel has never yielded more than a comparatively feeble light—now to obtain for the purpose of our invention a carbon absolutely pure or at least more nearly approaching absolute purity than any heretofore known, we proceed as follows— * * *"

With the methods known for producing a vacuum in 1846, the inventors must have been aware that there was gas within the lamp chamber. They attached no significance to this fact but noticing that an evaporation of the carbon took place resulting in a blackening of the globe apparently assumed that it was due to impurities in the incandescent carbon and that a method of overcoming this difficulty was to use a purer carbon, to the method of manufacturer of which the patent in part relates.

167 x-Q. Was it not Greener & Staite's plan to remove all gases from the lamp chamber, so far as was practicable with the means then available for such purposes?

A. From the fact that Greener & Staite contemplated the use of carbon burners and mention the use of an air-tight chamber, although they say nothing as to how it is to be constructed, I suppose it was their intention that the air should be removed from the lamp chamber, as far as this could be done by the means then known to the art, but solely for the purpose of getting rid of the oxygen of the air. I think that the suggestion in the patent that an air-tight vessel was to be used would not have resulted in obtaining any better lamps than that patented by Roberts in 1852, already referred to, or in revealing to the art the necessity of removing other gases than the oxygen, or that it would have led to the discovery that evaporation of the carbon was to be prevented by using a high vacuum and not by the purification of the carbon as was supposed by the inventors.

168 x-Q. Still, was it not the idea of Greener & Staite, as taught in their patent, that if the lamp chamber of an incandescent lamp were to be exhausted, all gases of every nature whatever being removed, so far as practicable with the means then known, and such chamber were to be made air-tight,

and if the carbon used for the burner were to be freed from impurities, the lamp would be a durable one?

A. No; I do not think that that is the correct way of stating it; I think in view of the state of the art at that time, that the inventors taught in their patent that the carbon burner was to be made more durable by preventing its evaporation *solely* by increasing its purity and that by exhausting the air (which would be practically the only gas in the chamber) as far as was possible by any any means then known to the art, and having the chamber as air-tight as was practicable, rapid combustion and the destruction of the carbon on this account would be retarded.

Adjourned to August 16th, 1890, at 11 A. M.

New York, August 16th, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

169 x-Q. Was it not their idea that by purifying the carbon sufficiently, and placing such carbon in an air-tight chamber, from which all gas was exhausted so far as practicable, the evaporation or volatilization of the carbon would be so far minimized as to make the incandescent lamp practically serviceable.

A. No, I do not think so. Their idea seems to have been that, if the carbon were purified, this alone would be sufficient to prevent the evaporation and that, if there was no oxygen in the globe to burn the carbon, the lamp would be serviceable; I do not think that they had the idea that all gases should be removed from the lamp chamber, but merely oxygen, neither do I think that the art would have understood that more than this was necessary.

170 x-Q. Do they say anything about oxygen in their patent?

A. No; neither do they say anything about other gases.

171 x-Q. Isn't air "another gas," and don't they in their patent speak of the removal of the air?

A. Air is a mixture of gases, one of which is oxygen. The patent makes no mention at all of gases of any kind, but says that the carbon burner is to be placed in an air-tight vessel. I understand that at the date of the patent this would have been an instruction to the art to remove and keep oxygen out of the lamp chamber and that if this were done nothing more was necessary.

172 x-Q. Wasn't it an instruction to take the *air* out of the chamber?

A. No; I think it was an instruction to remove oxygen from the chamber. The most natural way of attempting to do this, at that time, was by pumping out the air.

173 x-Q. Isn't it true that Greener & Staite recognized the fact that the presence of air in the lamp chamber was injurious, without indicating how its presence operated to injuriously affect the carbon; and isn't it a further fact that they assumed that the removal of the air would eliminate this source of danger to the carbon?

A. They, as well as all others skilled in the art, knew that the presence of air was injurious solely because the oxygen in it would burn the carbon, and assumed that by removing the air, danger on this account would be prevented. I think, however, that they did indicate in the patent, and state to those skilled in the art, how the presence of air injuriously affected the carbon, although it was already perfectly well known.

174 x-Q. What is your warrant for saying that Greener & Staite knew that the air was injurious "solely because of the oxygen in it"?

A. I have no means of knowing this, excepting through the character of the instructions which the art received from the specification of the patent as judged by the subsequent history of electric lighting. So far as I know, prior to the date of the patent in suit, it was supposed that the oxygen of the air was the only destructive agent contained in it.

175 x-Q. Let me see if I understand you. Is this

your position: That although the Greener & Staite patent contemplates the removal of the air from the globe, and does not suggest that the destructive character of *the oxygen* in the air was their sole reason for removing it, yet it is fair to assume that this *was* their *real and only* reason for removing the air, inasmuch as subsequent to the date of their patent, and prior to the date of the patent in suit, no one seems to have suggested that it was necessary for the preservation of the carbon to remove anything but the oxygen?

A. No; that is not exactly my position. So far as I know, after the date of Greener & Staite's patent, and up to the date of the patent in suit, the art supposed that gas in the lamp chamber, excepting oxygen, did not operate injuriously. In view of this fact, I think it not only a fair, but a necessary assumption that the Greener & Staite patent instructed the art merely to remove the oxygen, which, as I have before stated, would have been most naturally attempted by pumping out the air. Of course, I do not pretend to be acquainted with all that the inventors may have known, but notwithstanding that their knowledge was revealed to the art in their patent, it does not appear that the art ever understood that Greener & Staite contemplated anything more than the removal of the oxygen, or understood from them that anything more than this was necessary, or that the presence of any other gas was detrimental.

176 x-Q. I now understand you to take the position that the Greener & Staite patent instructed the art to remove only the *oxygen* of the air, and that this is a "necessary assumption," based, not upon any declarations found in the patent, but upon the fact that everybody, after the date of said patent and prior to the date of the patent in suit, supposed that the oxygen in the lamp chamber, and that alone, was what operated to destroy the carbon. Is that the position which you hold as expressed in your last answer?

A. No. I assumed that the art was aquainted with and instructed by the patent, and that in view of the declarations contained therein, and the subsequent

efforts of the art to make a practical lamp, it was supposed that it was only necessary to remove the oxygen from the lamp chamber.

Adjourned to August 18th, 1890, at 11 A. M.

New York, August 18th, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

177 x-Q. Supposed by whom?

A. By Fontaine, Bernstein and Prof. Morton as cited in answer to 163 x-Q., and, so far as I know, by those who endeavored to make or described a method of making incandescent carbon lamps, and by others who after the appearance of Edison's lamps, hastened to express their opinion that it would not be durable.

178 x-Q. In your answer to 163 x-Q. you have quoted certain words of Prof. Morton. Do you hold that those words constitute a positive theory on his part that the presence in the lamp chamber of other gases than oxygen have no effect whatever upon the durability of the carbon, or, in other words, that the carbon would wear out just as soon if all gases whatever were withdrawn from the globe?

A. I do not think that he had a positive theory on the subject, but that his knowledge as a scientific man led him to the opinion, that as far as the durability or wearing out depended upon the evaporation, the rapidity with which this would take place would not depend upon the amount of gas in the globe; for he says that

> "The carbon rods are said not to waste away in these lamps. * * * My opinion is that this is *only* because they have not been subjected to strong currents, * * * "

The italics are mine.

179 x-Q. Would not these words be entirely consist-

ent with the theory on his part, that the presence of inert gases in the lamp chamber is injurious to the carbon, gradually wearing the same out by mechanical abrasion by the currents set up in the gas as the carbon becomes heated, and that these currents will become more rapid, and therefore stronger and more destructive, the more highly the carbon is heated?

A. I do not think so, when we take into account the fact, as appears from other parts of his lecture, that he was comparing a Konn lamp, which was partially exhausted, with a Sawyer-Man lamp, which was filled with nitrogen at atmospheric pressure. Under these circumstances, I do not see how Prof. Morton could consistently have held the theory which is in the question, because, in spite of the fact, that the two lamps contained different amounts of gas, he says that the wasting away is only due to the strength of the current.

180 x-Q. What he says is this—that he is of the opinion that the reported stability of the carbons in the Sawyer-Man lamp was due to the fact that they had "not been subjected to strong currents." Do you intend to express the opinion that these words are equivalent to the statement that it is *the current alone* (when strong enough) that produces the destruction of the carbon, and that they exclude the idea that the strong current would produce this result in the Sawyer-Man lamp by means of the movements which it would set up in the gases enclosed in the globe?

A. I do not think that Prof. Morton could have had the idea that the strong current would produce the wasting away because of the movements which would be set up in the gases within the globe, because he was comparing the effect of the current upon a Konn lamp with a partial vacuum and its effect upon a Sawyer-Man lamp without a vacuum. Prof. Morton seems to have had no definite idea of the real cause of this evaporation, for in speaking of the Konn lamp, he says:

> "Various slight modifications of this lamp have been made and elaborately experimented with; but they all show the same essential characteristics. The first of these is that as long as any oxygen remains in the vessel the carbon rods consume rapidly, the first one generally lasting only twenty minutes. The second carbon will, however, last two hours if the light does not exceed forty burners; *but even when all active gas has been removed the corbon suffers a sort of evaporation.*"
>
> The italics are mine.

While recognizing that strong currents produced the wasting away of the carbon, Prof. Morton apparently had no definite idea of its true cause, but ascribed it to a "sort of evaporation" just as heat vaporizes water.

181 x-Q. Inasmuch as Prof. Morton "had no definite idea of the true cause" of the wasting away of the carbon, and inasmuch as the qualified expression, "*sort of* evaporization," used by him, indicates that he did not positively regard the operation as an *actual* vaporization, how can you say that his words prove that he thought that the presence of the gases other than oxygen had nothing whatever to do with this destruction of the carbon?

A. While, as I have said, Prof. Morton, in my opinion, had no definite idea of the true cause (by which I meant the absolutely exact reason) for the wasting away of the carbon; I think that his statement indicates that, in his opinion, the wasting away was due to some kind of a vaporization, and that he had no idea that the presence of other gases than oxygen had anything to do with this action, because he says that this takes place "even when all active gas has been removed."

182 x-Q. Do you also think that he had an idea that the presence of other gases than oxygen did *not* have anything to do with this action?

A. Yes. From what Prof. Morton said, I think that he was of the opinion that other gases than oxygen did not cause this action.

183 x-Q. I understand you to hold that the patent in suit contemplates the removal from the lamp

chamber, not only of the oxygen of the air, but also all other gases. Is it your idea that Mr. Edison's chief merit as an inventor, so far as concerns the invention to which said patent relates, consists, not in the removal of the oxygen, or in the suggestion of the desirability or necessity of its removal, but in the circumstance that he was the first to recognize the fact that the other gases, such as are found in the air, either as constituents of the same or otherwise, are in some way destructive of the carbon, and was the first to instruct the world that because of this destructive action of these other substances it was essential to the working of a good and practical lamp that all gases be removed from the globe?

A. The ascertaining of the fact that the carbon became practically stable when all gases were removed from its presence was, in my opinion, a discovery which I understand Mr. Edison made and first announced to the public in the specification of the patent in suit.

In my opinion the lamp described in this patent was the invention.

Adjourned to August 19th, 1890, at 11 A. M.

New York, August 19th, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

184 x-Q. Apparently you deem it of moment to make prominent a distinction between what you regard as Mr. Edison's "discovery" and Mr. Edison's "invention." I will therefore put the matter before you on this wise, in regard to what you call his *discovery*.

I assume that you will agree with me that at the time when Mr. Edison took up the problem of electric lighting it needed no prophet risen from the dead to teach the world that if carbon was to be successfully used for the burner of an incandescent lamp, it must be enclosed in a space free from oxygen; also, that if the lamp was to be durable, this exclusion of the oxygen from the carbon must be secured by means that would be practically permanent; or, to put it in other words, I assume that you will agree with me that the world already knew that it was essential to the durability of a carbon burner in an incandescent lamp that the oxygen at least of the air be removed from contact with the burner, and that this separation of the oxygen and the carbon be made practically enduring. Under these circumstances do you hold that, so far as Mr. Edison's invention, the subject of the patent in suit, is based upon any *discovery* made by him, that *discovery* consisted solely in the fact that he was the first man to find out that it was essential to the durability, and therefore to the success, of a carbon lamp that all the other gases, as well as the oxygen, should be excluded, and permanently excluded, from the lamp chamber?

A. As far as the durability of the burner depended upon the prevention of its destruction by combustion, I understand that the world knew that it was necessary to remove and keep oxygen out of the lamp chamber, and I further understand that with the lamps having chambers filled with inert gases it was generally understood that this was so satisfactorily accomplished that oxygen played no part in the destruction of the burners of such lamps and that the efforts to make a practically enduring lamp, as far as avoiding the detrimental effects of oxygen was concerned, were successful; but that, in spite of this difficulty having been successfully overcome, still other causes prevented the burners from being durable. So far as Mr. Edison's invention was the outcome of any discovery, I think it was the discovery that a carbon burner, even when very small in diameter, and of high specific resistance, would be practically stable when enclosed in a globe, from which all gases were removed, and from which they could be permanently excluded; I use the word "discovery" in this connection in the following sense, that it is the ascertaining of a new property of carbon.

185 x-Q. Would you then hold that Mr. Edison would have made just as great an "invention" if, following out the instructions of King and of Greener & Staite and of Roberts, in regard to placing the carbon of an incandescent lamp in a vacuum, he had availed himself of the improved means known to the art in 1879 for creating a vacuum, and thus had secured a higher vacuum than his predecessors were able to get, and also had availed himself of the improved means for maintaining such a vacuum permanent which he used in the early platinum lamp (viz., a seamless all-glass globe), even if he had not made the "discovery," which you attribute to him, that practically the stability, and therefore the utility, of such a lamp depends upon the permanent exclusion from the globe of the other gases as well as the oxygen of the air?

A. Assuming for the moment that the statement in the question of what purports to be the facts, is true (which I do not admit), I think that it would have required invention to bring together into one combination the all-glass chamber, with platinum conducting wires fused into its walls, and containing a carbon burner of small diameter in a high vacuum, the whole being so ordered and arranged as to result in a practically durable lamp, like that described in the patent in suit, by the use of which the problem of subdividing the light would be solved.

186 x-Q. Evidently you miss the point of my question. Suppose that Mr. Edison had constructed the identical lamp which is shown and described in his patent, but had not discovered that its durability or efficiency was in any way dependent upon the fact that he had taken out from the globe the other gases contained in the air, as well as the oxygen; would you say that the making of such a lamp, under such circumstances, would have constituted the invention covered by the patent in suit?

A. I think that the making of such a lamp, even although it be assumed that Mr. Edison did not know the reason why it was durable, although aware of the fact, would have been the invention described in the patent in suit. As I understand it (as I have often said before) prior to the date of Edison's patent the art supposed that a carbon burner would necessarily wear out very rapidly, even when no oxygen was present, and did not ascribe this action to other inert gases, and in fact, considered that the most promising way of making the burner durable was to keep out oxygen by filling the globe with an inert gas. Separable lamp chambers, with metallic caps, were also deemed essential, so that the burners could be renewed; because their life was so short that any mode of construction, which would have made it necessary to throw away the lamps when the burners failed, would have made the cost of lighting with such lamps so great as to prohibit their use.

In view of these facts, I think that no one would have supposed that a carbon burner would be durable if all the gases were removed from the globe, but would have been deterred from attempting to do this because of the recognized difficulty of obtaining and preserving a high vacuum with a separable lamp chamber and also because the air which would leak into the globe would contain oxygen and hasten the destruction of the burner on this account. I also think, in view of the fact that the carbon rods which were used in the old lamps wore out rapidly and endured for only a few hours, that no one would have had the temerity to substitute carbon burners of small diameter, like those described in the patent in suit, in place of the old rods, with the expectation of their withstanding at all the destructive action which wore out the rods so rapidly, or would have supposed that there would be any advantage in placing them in lamp chambers in which a high vacuum could be obtained and preserved.

All the foregoing answer after the first sentence is objected to as not responsive.

187 x-Q. In your answer to Q. 12 you assume that Mr. Edison discovered "a new physical property of

carbon," and in answer to 160 x-Q, you have made some explanation in regard to what you mean by that assumption. As I understand you, this new physical property of carbon, which you say was discovered by Mr. Edison, consists in the susceptibility of carbon to evaporate or wear out when brought to incandescence in the presence of other gases than oxygen, by reason of the presence of such gases, even though no oxygen be present, which effect disappears when these gases are removed. Does this correctly define the "new physical property of carbon," the discovery of which you impute to Mr. Edison, and which, apparently, in your estimation, has much to do with his merit as an inventor in connection with the subject matter of the patent in suit?

A. As I understand it, Mr. Edison discovered that when a carbon burner was enclosed in a high vacuum the destructive action (variously termed "evaporation," "volatilization" and "disintegration") which took place when it was surrounded by a gas, (even though containing no oxygen) ceased to such an extent that the burner became practically durable.

Adjourned to August 20th, 1890, at 11 A. M.

New York, August 20th, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

188 x-Q. In your last answer you make a statement of a fact, which you assume Mr. Edison to have been the first to observe. Does not my last question correctly define the alleged "new physical property of carbon" which depends upon or is connected with that fact? If not, how would you define the "new physical property of carbon" referred to in your answer to Q. 12?

A. I think that the question defines it with substantial accuracy, although I preferred to state it in another way.

189 x-Q. Is this alleged newly discovered physical property of carbon characteristic of one size rather than another?

A. I do not understand that it is.

190 x-Q. What other physical properties of carbon, if any, do you understand that Mr. Edison discovered?

> Objected to as immaterial, irrelevant and not proper cross-examination, as to which the defendant makes the witness its own.

A. I belive that Mr. Edison made the discovery above referred to with a burner very small in diameter, which was quite porous, and consequently of high specific resistance, and that he was the first to observe that such a burner possessed sufficient mechanical stability to make it suitable for practical use as the burner of an incandescent lamp by which the light could be subdivided. I hardly think that the scientific world would dignify the ascertaining of this fact, that the small and porous carbon had mechanical stability, by the term "discovery," although I suppose that the finding out of any new fact whatever practically amounts to that.

191 x-Q. Do you regard this last-mentioned so-called "discovery," made by Mr. Edison, as the discovery of a *physical property* of carbon?

A. In a certain sense, I should say yes, for the reason that I do not think that, prior to the date of the patent in suit, the art would have supposed it possible that carbon burners, very small in diameter, would have sufficient mechanical stability to make their use practicable. I consider that, in a certain sense, to find out that such a burner is mechanically stable would be a discovery of a new property of carbon.

192 x-Q. Isn't this a more correct statement of the matter; that Mr. Edison discovered the new property of carbon set forth in 187 x-Q. by certain experiments

which he made with a very small carbon burner, and that those experiments, although made with a small carbon, demonstrated the existence of this property in carbons of all sizes? If so, how can you hold that the observation of the fact that carbon, when protected by a high vacuum, can be reduced to a definite tenuity, is the discovery of a new "physical property of carbon"? In other words, what has the size of the carbon to do with the physical properties under discussion?

A. Since the date of the patent in suit it has of course become known that the size of the carbons of incandescent lamps has very little to do with the question of mechanical stability, but before that time I think that, aside from the idea that the evaporation which took place in the old lamps necessitated the use of burners of large diameter, it would not have been supposed possible to use burners of very small diameter because of a want of a mechanical stability. In my opinion Mr. Edison found out that burners of small diameter did have mechanical stability, and therefore demonstrated the existence of this property in carbons of small size which, before the date of his patent, I think would be ascribed only to carbon rods.

193 x-Q. Granting that Edison proved by experiment that the mechanical stability of a carbon burner when reduced to a very small cross section was much greater than any one would have supposed in advance of the test, and so much greater even as to be serviceable for practical lighting. Do you think that this can fairly be called the discovery of a *new physical property of carbon?* Is it not rather the ascertainment—discovery, if you please—of the extent to which a previously well known physical property of carbon, viz., mechanical stability, will manifest itself under certain given conditions?

A. Understanding that I am asked to express an opinion upon the last sentence of the question I answer yes, with the further understanding that I believe that no one would have supposed that a carbon of small diameter could, under any circumstances, have sufficient

mechanical stability to make it available as the burner of an incandescent lamp.

194 x-Q. By this answer I understand you to admit that this was not a discovery by Mr. Edison of a new physical property of carbon?

A. All things considered, I think that it is probably more correct to say, not that Mr. Edison discovered a new physical property of carbon, but that he did discover that carbons of very small diameter had mechanical stability to an unsupposed extent, and sufficient to make them suitable as burners of incandescent lamps.

195 x-Q. I now repeat a former question, in substance as follows: What other "physical property of carbon" do you understand Mr. Edison to have discovered besides the one which you have already imputed to him and the nature of which is formulated in my x-Q. 187?

A. I do not know of any other, but, as I said in answer to 190 x-Q., which is repeated in the above question, I believe that Mr. Edison was the first to find out that a carbon very small in diameter possessed sufficient mechanical stability to make it suitable as a burner of an incandescent lamp.

196 x-Q. He was also the first, was he not, according to your theory of the general subject under discussion, to find out that a carbon of large diameter, or of medium diameter, when used as the burner of an incandescent lamp, had sufficient mechanical stability to make it suitable for such use?

A. Not in every respect. I think that the art would have very properly considered that the carbon pencils of the old lamps were sufficiently large, and therefore strong enough, to protect them from being broken by mechanical shocks and the handling incidental to their use, but owing to the rapid evaporation, which soon resulted in the destruction of the burner, did not have an opportunity to ascertain whether it would prove mechanically unstable after prolonged use. The construction by Mr. Edison of a lamp in which this rapid evaporation was prevented gave to the art means for ascertaining the facts not known before, which, in my opinion, are as follows: First, that carbons of very small diameter are, as far as mechanical shocks incidental to the manufacture, transportation and use of the lamps are concerned, stable; second, that carbons which are so large that there could never be any question about their ability to resist an ordinary shock, and also the small carbons before mentioned, will withstand the effects of the current without breaking for a length of time sufficient to make lamps with such carbons practically durable.

Adjourned to August 21st, 1890, at 11 A. M.

NEW YORK, August 21st, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

197 x-Q. Apparently, you deem Mr. Edison entitled to much credit because of the discovery which you impute to him, that carbons "of very small diameter" are mechanically stable, while you admit that, prior to Mr. Edison's work, it was well understood by the art that carbons of larger diameter (the size, however, not being indicated by you) possessed this same quality of mechanical stability. In order that the Court may understand the nature of this alleged discovery of Mr. Edison's, will you please to state the size of the largest carbon which would fall within your designation of "very small diameter," and to which, therefore, this "discovery" of Mr. Edison's would apply?

Objected to as not proper cross-examination as to which defendant makes the witness its own.

A. I have not, that I know of, said or intended to say that, prior to the date of the patent in suit, the art knew that a carbon burner of large diameter had mechanical stability, excepting in respect to its ability to

resist ordinary mechanical shocks without breaking. As to the effect of the current and heat upon the mechanical stability of the burner, I believe that it was not until after the date of the patent in suit, and with burners enclosed in a very high vacuum, that it was ascertained that they would be stable in this regard, irrespective of what their diameters might be within the limits at present fixed by the largest and smallest diameters of the burners of the various types of lamps in use to-day. I am unable to state the size of the largest carbon which Mr. Edison found out would be mechanically stable under the effects of the heat and current, excepting to say that, in my opinion, he discovered this fact at least for some sizes of carbons and gave the art the means by which it ascertained that all other sizes of carbons, used in modern incandescent lamps, had this same stability. As to the ability of the carbons to resist mechanical shocks, I do not know the diameter of the largest size from which Mr. Edison ascertained this fact. After Mr. Edison had found out that a carbon very small in diameter would successfully resist ordinary mechanical shocks, which I believe he was the first to do, I think that every one would have at once recognized that the larger size would be durable in this respect.

198 x-Q. It seems to me that you confuse the term "mechanical stability." In using this term do you refer simply to the capacity of the burner to resist *mechanical shocks* in the manufacture of the lamp, or in its transportation, or such as may occur in its use, or do you also include the capacity of the burner to withstand disintegration, or rupture, under the action of the current and the heat generated thereby?

A. By mechanical stability of the carbon burner I refer to its ability to withstand mechanical shocks and the effects of the heat and current without breaking. This is outside the question of evaporation which in modern lamps does not, I believe, cause the burner to break.

199 x-Q. So far then as this term "mechanical stability" has to do with the capacity of a carbon

burner to withstand the effects of the heat and current was not Mr. Edison the first, *according to your understanding of the matter*, to discover that carbon *of any size* had sufficient mechanical stability to make it serviceable for the burners of incandescent lamps? In other words, was not this discovery, which you impute to Mr. Edison, in fact, independent of the size of the burner?

A. The facts are, as I understand it, that Mr. Edison made the discovery that carbons of very small diameter had this stability, and that others as well as himself, with the aid of the experience and skill which they afterwards acquired, ascertained that it was possible to make carbons of any diameter not larger than the largest in common use to-day which would possess this stability sufficiently to make them practically durable. With this understanding of the facts and the limitation which I have put upon the diameter of the carbon, I should say that the discovery referred to in the question was independent of the diameter of the burner.

200 x-Q. Don't you hold just this, and isn't this a fair summary of your views upon this point, as heretofore expressed, viz., that, leaving out of the account mere mechanical shocks, no one before Mr. Edison's work in the premises either knew or believed that a carbon burner, however large or however small it might be, had sufficient mechanical stability to withstand the destructive action of heat and the electric current long enough to be practically useful; that Mr. Edison, by experiments made with a carbon burner of very small diameter found that carbon even when reduced to so small a size did possess that degrees of mechanical stability just indicated; and that thereupon it became apparent, both to him and to all others skilled in the art, that this degree of mechanical stability was practically independent of the size to which the carbon is brought?

A. I believe it was understood by the art that carbon burners, irrespective of their size, did not have the mechanical stability to withstand the action of the heat and current requisite to make them practically useful, but I think that the art was of the opinion that whatever stability could be obtained was to be looked for in carbons of large diameter, and that the use of small carbons like those in the ordinary modern lamps would not have been thought of or attempted. I think this view of the matter is substantiated by the fact that the efforts to make burners, which should be durable in every respect, were confined altogether to the use of carbon rods having a cross-section very much greater than that of the burners of the common modern lamps. In support of this opinion that the art considered that the best results as to mechanical stability would be obtained by using large burners or rods, I quote the following extracts from an article entitled, "Some Reflections in Regard to the New Lamp of Mr. Edison," which was written by Du Moncel and published in "La Lumiero Electrique," on February 28th, 1880:

> "It (meaning Edison's new lamp) does not even offer the ingenious arrangement of Mr. Konn's lamp, which prevents the extinction of the light in case of the rupture of the incandescent carbon. * * * To-day Mr. Edison takes us backwards, and it is the Lodyguine lamp which he resuscitates under a different form. (The burners of both of these old lamps were carbon rods). * * * It is besides difficult to admit that this horse shoe of charcoal, so slender and so delicate, does not deteriorate by a prolonged incandescence; for besides the calorific action which tends to disaggregate the carbonaceous particles, a mechanical action of the current is produced which tends to carry them off and deposit them on the sides of the receiver, as is noticed in the tubes of Geissler."

It would appear that Du Moncel, who was a well-known scientist and electrician, held the opinion that the heat of the current would cause a diminution in the mechanical stability of all carbon burners or as he says would "disaggregate the carbonaceous particles." Evidently he contrasted the carbon rod of the Lodyguine lamp with what appeared to him to be the very "slender" and "delicate" burner of the Edison lamp and obviously, I think, to the disadvantage of the latter; for the reason that, being slender and delicate, the effect of the heat would be to cause it to have a very much shorter life.

Adjourned to August 22d, 1890, at 11 A. M.

New York, August 22d, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

(Witness continues): Now, contrary to this opinion which I think the art held, prior to the date of the patent in suit, viz: that the larger the diameter of the burner, the better it would resist the calorific action, it was found out by Mr. Edison that burners of very small diameter were durable when subject to this action, and later on, by himself and others, that an increase in diameter resulted in a diminution in mechanical ability to withstand the heat. In fact, it is only through the great skill and experience which the art has acquired since it became known that small burners are durable, that it has become possible to make practically durable burners of the largest sizes now in use.

In view of my understanding of this matter, I do not think that, when it became known that a small burner was durable, it was apparent to Mr. Edison and others that the degree of mechanical stability was independent on the size of the burner.

201 x-Q. From this I understand you to hold that neither Mr. Edison, nor any other person skilled in the art, on discovering or being made acquainted with the fact that carbon, when reduced to one particular size, possesses sufficient mechanical stability to make it serviceable as the burner of an incandescent lamp, was justified in the conclusion that the same carbon, when reduced to a different size, would have the same degree of mechanical stability. I use this term "mechanical stability" in the same sense in which we have more lately been using it, viz: the capacity of the carbon to withstand disaggregation and deterioration under the action of the current and the heat generated thereby.

A. No, I do not think that any one is justified in assuming that because the heat, operating according to the laws of nature, has a given effect upon the mechanical stability of a burner of one diameter that it will have this effect to the *same degree* upon a burner of smaller diameter, upon the general principle held by scientists, that nothing can be known concerning the effect of the laws of nature excepting it be ascertained through facts obtained by experiment. After Mr. Edison ascertained that a burner of very small diameter was mechanically stable and gave the art knowledge of the means by which he ascertained this fact, I think it would have been naturally inferred that other burners, not varying greatly in diameter from this one, would have, practically, the same stability (although there would be no justification in assuming this to be absolutely true), and that the art would at once very naturally ascertain the correctness of this inference by testing burners of various diameters under the conditions employed by Mr. Edison. I do think however that the art would be justified in assuming that, if one burner had sufficient mechanical stability to make it practically durable, the stability of another burner a little smaller in diameter would not differ so greatly in amount from that of the first as to prevent it from also being practically durable,

202 x-Q. I do not understand your position. You say, in substance, that if, contrary to the assumed previous belief of the art in the matter, one had found out that a burner of a given size had sufficient mechanical stability to make it practically durable, the art would be justified in inferring therefrom that another burner varying "*a little*" in size from the first one, would also have sufficient stability to be practically durable. Do you mean by this to indicate that such an inference

would not apply generally to burners of all sizes, and particularly to those of larger diameters than the first one; and, if not, what are the limitations implied by your use of the term "*a little*"?

A. Yes, I think that this inference would only apply to burners varying a little in diameter from the particular one referred to, and not generally to burners of all sizes. I am unable to state within what variations in diameter the inference would be justifiable, not knowing of any information contained in the literature of the art upon this point.

203 x-Q. Is it not a fact that the mechanical stability of a carbon burner depends very largely upon the nature of the material out of which the carbon is made, and also upon the treatment to which such material is subjected in the process of carbonization and subsequently?

Objected as immaterial and not proper cross-examination.

A. Yes.

204 x-Q. Might it not happen, therefore, that a comparatively large carbon burner, made out of one material and by one process of carbonization, would have very much less mechanical stability (whether we regard that term as implying power to resist shocks or power to withstand the deteriorating effect of the electric current and the heat produced by it) than another carbon burner of much smaller diameter but made out of different material and by another process of carbonization?

Same objection.

A. It is possible, by proper selection of materials and suitable processes of carbonization to produce these results, but I do not know that the small burners of modern incandescent lamps resist mechanical shocks practically any better than the large burners.

205 x-Q. Suppose a carbon to be made of the size

which is used in the Edison sixteen-candle-power new lamp, or the Edison ten-candle-power new lamp, such carbon being made from a strip of paper by any of the processes of carbonization that were known to the art prior to the year 1879 and without being subjected to any of the treatments subsequent to this carbonization (such as the hydro-carbon treatment, or electrical heating while the lamp is on the pumps) which the art has found it necessary to adopt in the manufacture of commercial lamps; would such a carbon, in your opinion, have sufficient mechanical stability for practical use as the burner of a commercial incandescent lamp?

Same objection.

A. No, not even if subjected to the hydro-carbon treatment and treatment on the pumps spoken of in the question.

206 x-Q. What else would be necessary to make such a carbon of practical value?

Same objection.

A. I do not know of any method of manufacturing carbon burners from paper and of the dimensions referred to in the last question which would make them sufficiently durable for practical purposes.

207 x-Q. How large must a burner manufactured from paper be before it would have sufficient stability to make it practically useful—assuming it to be sealed up in the lamp globe without being treated, subsequent to its carbonization, either by the so-called hydro-carbon treatment or by electrical heating on the pump?

Same objection.

A. Under these circumstances the burner, whether large or small, would not be practically durable. Even if the paper carbon were subjected to the hydro-carbon treatment, it would have no durability, if it were not electrically heated on the pump.

Adjourned to August 23d, 1890, at 11 A. M.

NEW YORK, 23d, 1890.

Met pursuant to adjournment at 11 A. M.

Present—R. N. DYER, ESQ., for complainant; MR. CLARKE, the witness.

At the request of Genl. Duncan the examination is adjourned till Monday, August 25th, 1890, at 11 A. M.

NEW YORK, Aug. 25th, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

208 x-Q. For commercial work, how far is this electrical heating on the pumps necessary when the carbon burner is made from other material than paper?

Same objection.

A. I believe that while the process of exhaustion is going on the temperature of the carbon is increased from time to time until it is brought up to normal incandescence or slightly above that point. At this temperature the process of exhaustion is continued until a high vacuum is obtained which will remain practically constant, thereby indicating that the gas in the pores of the carbon has been expelled.

209 x-Q. What I wish to know is this—whether in the practical manufacture of carbons for commercial lamps out of other materials than paper it is found necessary to make use of this electrical heating on the pumps?

Same objection.

A. Yes.

210 x-Q. Is that the case irrespective of the size of the burner?

Same objection.

A. Yes, at least for all sizes between the smallest and largest used in modern incandescent lamps.

211 x-Q. Is this also the case when the burners have been treated with the hydro-carbon treatment subsequent to their carbonization?

Same objection.

A. Yes.

212 x-Q. Suppose the first carbon burner made by Mr. Edison had been only *a little* smaller than the carbons previously used for incandescent lamps—say, if you please, two or three times as small—and on trial he had found it to have sufficient mechanical stability to make a practically durable lamp, what assurance could he have had from this that a burner of *very much* smaller cross section than that, say ten or twenty times as small, would also have been sufficiently stable for practical purposes?

A. Assuming that Mr. Edison had been able to, and did first ascertain that the burner two or three times smaller in cross-section than those which were used in the old lamps had sufficient mechanical stability to make it practically durable, I do not think that from this he would have assumed that a burner ten or twenty times smaller would also be stable enough for practical purposes, but in my opinion he would at once have made the experiment under the same conditions with the small burners, in order to ascertain the facts.

213 x-Q. For the same reason which lies back of your last answer, do you not also think that if Mr. Edison had made his first carbon burner as large as those that had been previously used in incandescent lamps, and on testing the same under the conditions of vacuum and lamp globe which characterized his first actual experiment with a lamp having a carbon burner, he had found such burner to be sufficiently stable for practical purposes, he would thereupon have made similar experiments, using burners ten or twenty, or perhaps forty times smaller?

A. I think so, assuming that at that time it had been possible to obtain the conditions and lamp structure by means of which the stability of the large carbon could be ascertained.

214 x-Q. I suppose that you would admit, further, that if the first lamp named in either of the last questions had been made by any person other than Mr. Edison, such a person, on observing the stability of the lamp, would at once have proceeded to construct and experiment with the lamps having the smaller burners, as set forth in said questions?

A. Yes, if skilled in the art.

215 x-Q. Why do you think that if the first practically durable incandescent lamp had had a carbon burner as large in cross-section as the lamps which preceded the date of Mr. Edison's earliest work, the maker of such lamp, whether Mr. Edison or any other person skilled in the art, would, on ascertaining its stability, have proceeded to make and test other lamps with burners ten, twenty, and forty times as small?

A. If the lamp referred to in the question had been made in the latter part of 1879, the maker would have understood that there would be an advantage in having a high resistance, and this I think, would have led him to attempt to make a burner having sufficient surface to produce the desired amount of light and also small in diameter in order that the requisite resistance might be obtained. Being in possession of a lamp which he knew was practically durable he would have been lead to make and test this burner of small diameter. When in the answers to the last three questions I said that the maker of the large burner would "at once" have attempted to make burners ten to forty times smaller I did not intend to say that these would be the first which he would have attempted to make. I think that he would naturally have made his experiments upon burners of one-half and one-quarter of the diameter of the larger burner and so on, and by thus gradually reducing the diameter would have soon arrived at the smallest practical size.

216 x-Q. Why do you introduce into your answer the condition that this first durable lamp (with large carbon burner) should have been made "in the latter part of 1879?"

A. In order to be certain that I am correct in understanding that the large burner referred to in the last four questions was assumed to have been made and tested in an absolutely tight chamber containing a very high vacuum at the time that Mr. Edison invented his carbon lamp.

Adjourned to August 26th, 1890, at 11 A. M.

New York, Aug. 26th, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

217 x-Q. By this I understand you to hold that if, at any time after Mr. Edison had made his platinum lamp with the highly exhausted all-glass globe, he or any other skilled person had substituted a carbon for the platinum burner of such lamp, the first carbon so used being as large in cross section as the burners used in the carbon incandescent lamps that preceded Edison's platinum lamp, and on trial such new carbon lamp had proved to be a practically durable structure, the experimentor would thereupon have proceeded to make other lamps, using the same globe and vacuum, with carbon burners of diameters ten, twenty and forty times as small as that of the first lamp. Does this correctly state your position?

A. The assumptions in the question being, as I look at it, absolutely contrary to the facts (as were also like assumptions in the last few questions), I find some difficulty in forming an opinion under circumstances which require such a violent stretch of the imagination. For, besides the fact that the art did not know that there would be an advantage in enclosing a carbon pencil in a very high vacuum, it was not even in possession of a lamp chamber, by means of which the experiment could have been tried. The all-glass lamp chamber with the platinum wires fused into its walls would not, in my opinion, have answered the purpose, for the reason that the large platinum wires, which would have been necessary for conducting the large current to the carbon rod, could not have been fused into the glass so that the joint would be permanent. The first successful lamp had the all-glass chamber and a burner of very small diameter, which made it possible to use small platinum wires, which could be permanently sealed into the glass without difficulty. Since that time the art by increased skill and experience has become able to effectually seal in larger wires and thus to increase the diameters of the burners which can be used. The extent to which this skill has been acquired is, I think, represented by those lamps having the largest platinum wires and carbon burners which are in use to-day, and in which, I believe, the burners are considerably smaller than those which were used in the old lamps.

If, however, for the moment we accept the assumptions in the question, I think that if Mr. Edison or another skilled person had enclosed the large carbon burner or rod in the all-glass lamp chamber containing a very high vacuum and with platinum conducting wires fused into its walls and had found that this lamp was durable enough to be useful, and if he were acquainted with the suggestions made by Mr. Edison in his French patent for a platinum lamp, to the effect that subdivision of the electric light was to be looked for by using burners of high resistance and of very small diameter, he would have understood that there would be an advantage in making such burners of carbon, providing they would be durable when made small enough to obtain the advantages necessary to accomplish subdivision and would have attempted to make such burners and would, I think, have been successful if the method by which the large carbon was made was also applicable to the making of the very small carbon.

218 x-Q. Is there a minimum limit to the size of the carbon burner which will remain stable, as against mechanical shocks and the effects of the electric cur-

rent and the heat when sealed up in an incandescent lamp?

A. Yes.

219 x-Q. Has this limit undergone any change since the lamps were first made and sold commercially?

A. Yes; increased skill and experience has made it possible to diminish the minimum size.

220 x-Q. What is it now?

A. I believe that the minimum size is represented by the burner of the Edison ten-candle-power lamp requiring an electro-motive force of 102 volts.

The burner of this lamp is 4.2 thousandths (0.0042) of an inch square.

221 x-Q. In 1881 what was the smallest size that could be used commercially?

A. I can only speak concerning the Edison Company. I believe that at that time they did not find it practicable in their ordinary sixteen-candle-power lamp to use burners less than 5.6 thousandths (0.0056) of an inch thick by 9.5 thousandths (0.0095) of an inch wide, while the burners in similar lamps now in use are 4.7 thousandths (0.0047) of an inch square.

222 x-Q. I find in your answer to x-Q. 200 the somewhat surprising statement not only that Mr. Edison found out that "burners of very small diameter were durable" when subjected to the calorific action of the electric current, but that he and others found out "that an increase in diameter resulted in the diminution of mechanical ability, to withstand the heat." What was the minimum size of burner beyond which this law of diminution of stability with increase of size applies?

A. I do not know what this minimum size was at any one time, but understand that with skill and experience the art was able to gradually increase the size of the burner without diminution of stability. I think that the first serious difficulty which the art encountered because of a diminution of stability with an increase in size was in attempting to make burners of the size of those in lamps of fifty-candle-power and upwards, and of those in lamps intended for use in series like the Municipal lamps. The art finally succeeded in making the burners of such lamps practically durable, and we may say that to-day the diminution of stability with increase of size applies to lamps having burners larger than those above mentioned.

223 x-Q. Then, as I understand you, as you proceed upward in the series of existing commercial incandescent lamps, beginning with the lamp having the smallest sized carbon, there is no diminution in the stability of the burner as the size increases, even up to the largest size?

A. I understand that it is now possible to make these burners so that they shall have very nearly or practically the same stability and that this result is accomplished in the manufacture of commercial lamps.

224 x-Q. What is the difference in cross-section between the largest and the smallest of the commercial lamps now made by the Edison Company?

A. The ten-candle-power and one hundred-candle-power lamps have the greatest difference in cross-section, that of the former being one-sixteenth of that of the latter, or to state it in another way, the one hundred-candle-power burner is three times as thick and five and one-third times as wide as the ten-candle power burner.

Adjourned to August 27th, 1890, at 11 A. M.

New York, August 27th, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

225 x-Q. Given in absolute figures, what are the respective cross-sections of these two burners.

A. The area of the cross-section of the one hundred candle-power burner is 0.00028224 of a square inch, and that of the ten candle-power burner is 0.00001764 of a square inch.

226 x-Q. You hold, as I understand it, that any diminution in the size of a carbon burner below the smallest size now used in commercial lamps, and also any increase of size above the largest size now used in commercial lamps, is attended in either case with such a falling off in the stability of the burner as to make such burners practically useless—in other words, that the law of stability which applies to carbons between these two limits does not apply when these limits are exceeded in either direction. Does this correctly represent your view?

A. Yes, I think that the largest and smallest sizes mark the limits beyond which the art is not able to go without the burners becoming so unstable as to make it impracticable to manufacture lamps with such burners for general commercial use. In making this statement I do not exclude the possibility of the art being able in the future to make practically durable burners, both larger and smaller than those now in use.

227 x-Q. And what is the present maximum limit?

A. The burner of the largest cross-section of which I have knowledge is 0.045 of an inch wide and 0.022 of an inch thick and the area of its cross-section is 0.00099 of a square inch, being one of the Thomson-Houston lamps. My information concerning the dimensions of this burner has been obtained from Complainant's Exhibit Schedule of Thomson-Houston Lamps, which I assume to be correct.

228 x-Q. In answer to x-Q. 201, you say that at the date of Mr. Edison's discovery (referring, as I understand, to the discovery which is spoken of in the patent in suit), "the art would have been justified in assuming that if one burner had sufficient mechanical stability to make it practically durable, the stability of another burner *a little smaller* in diameter would not differ so greatly in amount from that of the first as to prevent it also from being practically durable;" and in your answer to x-Q. 202, you assert that this inference, which you say would have been justifiable on the part of the art, "would apply only to burners varying *a little* in diameter from the particular one referred to, and not generally to burners of all sizes."

Now, do you hold that in 1879 there was such a radical difference between a carbon "rod" (such as you understand Lodyguine, Sawyer & Man, and others to have used in their incandescent lamps, prior to Mr. Edison's discovery), and the very small burner referred to in the patent in suit under the name "filament" that one could not at that date have reasoned with confidence from the one to the other, so as to have been justified in the conclusion that what was observed to be of utility in the making, or the use of the one, would also in like manner and for the same reasons be of utility in the making and the use of the other?

Objected to as indefinite.

A. In my opinion, if it had been ascertained that the carbon rod, which was used in old lamps like those of Lodyguine and Sawyer & Man, was stable, no one would have been justified in assuming that whatever was observed to be of utility in the making or use of this burner would be equally applicable and advantageous in the making or use of the burners mentioned in the patent in suit.

229 x-Q. Is your reason for this conclusion to be found in your assumption that carbon possesses a physical property not known to the world until it was discovered and revealed by Mr. Edison?

A. Not exactly. It is founded upon my opinion that, if the art had ascertained that this carbon rod was stable under proper conditions, it would have considered that this was due to the fact that, being large, it was able to withstand mechanical shocks and the calorific action of the heat tending to disaggregate its particles and break it, and would have assumed that by making it of very small diameter (if this could be done) it would not in these respects be stable enough to make it of practical utility; the incorrectness of which assumption I believe Mr. Edison was the first to ascertain.

230 x-Q. Of course, you will not go so far as to assert that if, at the time referred to (in the year 1879, prior to the date of Edison's alleged discovery) it had been ascertained that a carbon "rod" (which I understand you to consider the proper term by which to characterize the burners used by Lodyguine, Konn, Sawyer & Man, and others) made out of a given material and by a given process, was stable when used under certain conditions as to degree of vacuum, character of lamp-chamber, etc., the art would not have been justified in assuming that carbons of somewhat smaller diameter would also prove to be stable if made from the same material and by the same process and used under the same conditions of vacuum, lamp chamber, etc.?

A. No, not if the word "somewhat" in the question implies that the difference is quite small.

231 x-Q. If, under the circumstances supposed, the art would have been justified in assuming that "somewhat smaller" burners would be stable, why would the art not have been justified in concluding that burners still smaller, if made of the same material and by the same process and used under the same conditions of vacuum and lamp chamber, would be stable?

A. Because I think that the art would have supposed that the possibility of making them so that they would withstand mechanical shocks and the action of the heat and current, would diminish in a much greater ratio than the reduction in their diameter and to such an extent as to cause said burners to be impracticable. Although the art, with the skill which it has acquired, is able to make burners of practically equal stability, which vary considerably in diameter, there is a limit beyond which the diameter cannot be diminished, which is represented by a burner a little more than four thousandths of an inch square. The hypothesis in the question would, I think, warrant the art in assuming that a burner would be durable no matter how small, an assumption which we know is not true.

Adjourned till August 28th, 1890, at 11 A. M.

NEW YORK, August 28th, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

232 x-Q. What is your warrant for saying that under the hypothesis of the last question the art would have supposed that the power of a carbon burner to withstand mechanical shocks, and the action of the heat and the electric current would diminish, with a reduction of the diameter of the carbon, in a much greater ratio than such reduction of diameter.

A. I think it was understood by the art that a diminution in the diameter of the burner would be disadvantageous, because it would reduce its stability. In support of this opinion I find that Du Moncel considered that even the carbon rods used by Lodyguine were not large enough to be stable; for he says (I translate from pages 162 and 163 of the second edition of his work on electric lighting, published in Paris in 1880, and evidently before he had knowledge of Edison's carbon lamp):

> "System of Messrs. Lodyguine and Kosloff: Of the different systems employed for obtaining luminous effects by the diminution of the cross-section of a good conductor, that made by Messrs. Lodyguine and Kosloff has given the most interesting results. These results, in 1874, also attracted much attention because the effects were somewhat comparable to those of which we have just spoken (the author here refers to the Jablochkoff candle); but in order to produce them a much greater electrical force was required, and the burners (*les organes*) raised from a red to a white heat, which were made from gas-carbon of small cross-section, did not possess the requisite (*désirables*) conditions of solidity and stability."

When Du Moncel first obtained knowledge of Edison's carbon lamp he expressed the opinion that the "slender" and "delicate" burner would not be stable, because the action of the heat would tend to disaggregate its particles. In answer to 200 x-Q. I considered this opinion expressed by Du Moncel at some length, and stated that, as I understood it, he was comparing Edison's burner with that of Lodyguine, and believing that the effect of the heat would be to cause the former to be very much less stable than the latter. Later on Du Moncel again stated what his impressions were upon receiving knowledge of Edison's invention, in an article published in La Lumiere Electrique, October 1st, 1881, in the following words:

> "All these attempts (referring to the efforts of prior inventors) had but partially succeeded, to say nothing more, when, in 1879, the new incandescent carbon lamp of Mr. Edison was announced, and many *savants*, and myself in particular, doubted the exactness of the allegations which came to us from America. The carbonized paper horseshoe appeared incapable of resisting mechanical shocks, and of supporting incandescence for any length of time."

The opinion, which apparently Du Moncel held, that a reduction in diameter would result in such a great diminution in stability as to cause the burner to be useless, would, I think, be also considered correct by others skilled in the art. Upon consideration, I think it would be probably more correct, but equally to the point, to say in the answer to 231 x-Q. that the art would have supposed that the possibility of making the burners so that they would withstand mechanical shocks and the action of the heat and current, would be so greatly diminished by reducing their diameter as to result in its being impracticable to make such burners.

233 x-Q. In your last answer, in drawing your conclusions from the quotations made from Du Moncel (whose claim to be an authority on these matters rests, as I understand it, upon his own boastful suggestion that he ought to be regarded as one of the "savants" of his time), you attribute to him the opinion "that a reduction in diameter—" meaning, as I understand you,

a reduction from the diameter of the old Lodyguine and Kosloff carbons—" would result in such a great diminution in stability as to cause the burner to be useless."

In answer to x-Q. 230, you have expressed the opinion that if a carbon burner of the size used by Lodyguine and others, before Mr. Edison's work, had been found stable, under given conditions of manufacture and use, the art would have been justified in assuming that a reduction in the diameter of such burners might be made without destroying the practical stability of the carbon, provided this reduction was not made too great.

When you expressed this opinion, did you consider that Du Moncel was included among the persons referred to by you in your use of the comprehensive term "the art;" or, would you now, on comparing your answer to x-Q. 230 with your last answer, qualify the latter by saying that what Du Moncel meant was, that if the diameter of the carbon was reduced *too much*, it would cease to be sufficiently stable for practical purposes, which I understand to be in exact accordance with existing facts, as admitted by you when you say that practically there is a minimum limit below which the reduction of the diameter of the carbon cannot be carried without impairing its stability to that extent that it becomes absolutely useless as a burner?

Objected to as indefinite, and as containing statements and assumptions not warranted by the evidence, in that, among other things, the counsel attaches to a statement by Du Moncel an unwarranted assumption as to the stability of the old carbons, and asks the witness to modify the meaning of Du Moncel's statement by that assumption.

Counsel for complainant also objects to the introduction into the questions by counsel for defendant of statements, such as that about the reputation of Du Moncel, which the witness is not asked to affirm or deny, and which are evidently intended to be taken as true by the Court without being established by proper evidence.

A. I see no reason for modifying my opinion, given in answer to 230 x-Q., concerning what the art (including Du Moncel) would have been justified in assuming. In the light of all the citations which I have taken from the writings of Du Moncel I think that he was of the opinion that as the diameter of the burner was reduced its stability would be rapidly dimished and that improvement was to be looked for, not in reducing the diameter, but, on the contrary, in increasing it, for he says that the burners used by Lodyguine and Kosloff, which he considered to be of "small cross section," did not possess the requisite conditions of solidity and stability. Still, although I believe as stated in my answer to 230 x-Q. that Du Moncel and others would have been justified in assuming that a reduction in diameter quite small in amount would still result in the burner being practically stable, I think that they would have considered that improvement in stability was to be looked for in the opposite direction.

234 x-Q. I still do not understand your reason for holding that, if, under given conditions of manufacture and use, a carbon as large as the old carbon burners had been found stable, the art in 1879 (prior to Edison's invention) would have been justified in assuming that a small reduction in diameter might be made without impairing the stability of the burner, *but that a larger reduction than this would have been wholly impracticable.* Will you, if possible, explain this matter more fully?

Objected to as immaterial and irrelevant since the witness has stated over and over again that the old carbons were not found stable and that the assumption upon which the question is based has no foundation in fact. Counsel for complainant feels it his duty to call the attention of the Court to the fact that the cross-examination has been made up largely of questions of this character, which are not warranted by the direct examination and cannot result in the exposition of any of the issues of the case; and to protest against the further protraction of an already protracted cross-examination by questions of this character.

Defendant's counsel states in regard to the length of the cross-examination that this has been rendered necessary by reason of the constant introduction by the witness into his answers of matters that were not relevant to the questions in connection with which they were introduced, but which, if admissible as a part of the deposition, could properly be introduced only on the direct examination; as defendant's counsel views the matter, the answers of the witness on cross-examination are made up very largely of such matters, notwithstanding the fact that informally the witness' attention has been repeatedly called to the objectionable character of his answers in this regard.

Defendant's counsel has not considered it necessary to enter these objections upon the record, because of the manifest intention of the witness not to confine himself in his answers to the scope of the question.

As regards the argument made by complainant's counsel under the guise of an objection, defendant's counsel has no other reply to make at present than to state that the fact upon which that argument proceeds only serves to emphasize the absurdity of the position which the witness has taken in regard to the views of persons skilled in the art in 1879.

Counsel for complainant replies that if the pursuit of the witness by counsel for defendant as to the views of persons skilled in the art in 1879 when the witness is asked to modify those views by assumptions which the witness protests are not true and which are directly contradictory to the views which he is asked to modify, has (due to the good natured attempts of the witness to answer such absurd questions) resulted in statements which seem absurd to

counsel for the defendant, the position now taken by counsel for complainant, that the cross-examination should not be further protracted by the continuation of this course, would seem to be sustained.

A. Although, as I understand it, the art considered that carbon burners would have no practical stability when tested under any of the conditions which could then be thought of as being at all suitable or necessary I believe that it was considered that an increase in the little stability (that is, their ability to last a few hours) which they did have was to be looked for by increasing rather than by diminishing their diameters. Now, if it be assumed that the carbon burners in old lamps had been placed under conditions which did render them practically stable, I believe that under this assumption the art would still have considered that greater stability was to be obtained by increasing the size, and that while it would be justified in assuming that a small diminution in diameter would not prevent the burner from being still stable enough for practical purposes it would not be justified in continuing to apply this assumption to still smaller diameters in view of the understanding that with a given diameter the stability would be constant and sufficient for practical purposes, and that its increase was to be looked for by enlarging rather than by diminishing the size of the burners.

Adjourned to August 30th, 1890, at 11 A. M,

August 30, 1890.

Met pursuant to adjournment.

Adjourned to Tuesday, Sept. 2, 1890, at 11 A. M.

NEW YORK, September 2, 1890.

Met pursuant to adjournment.

Present—G. P. LOWREY and R. N. DYER, of counsel for complainant; S. A. DUNCAN, of counsel for defendant.

CROSS-EXAMINATION OF THE WITNESS, C. L. CLARKE, RESUMED:

235 x-Q. In your answer to 47 x-Q. you say that "the efforts of the art have been continually directed towards obtaining lamps having burners of exceedingly small cross-section," etc.; to what period of time—that is, since what date—did you intend that statement to apply?

A. From the time beginning with the date of the patent in suit. The answer had reference to lamps with carbon burners.

236 x-Q. Did you intend by 47 Ans. to suggest that since the date of the patent in suit the art has constantly been seeking to obtain, and has in fact obtained, carbon burners of smaller cross-section than it was possible to secure by the methods known to the art during the period immediately succeeding the grant of the patent?

A. Yes; understanding that the life of the lamps in all cases is assumed to be the same.

237 x-Q. Has this result, as you understand it, been secured by means of inventions made, or at least revealed to the public, since the date of the patent in suit?

A. I am not acquainted with the details of the processes pursued in the commercial manufacture of incandescent lamps (I refer more particularly to the manufacture and treatment of the burners). Neither am I well acquainted with the history of the art in this regard as revealed by patents for the manufacture of the burners granted since the date of the patent in suit, having had no particular occasion for inquiring into this subject. I am therefore unable to say how much of the present ability to reduce the diameter of the

burners is due to skill and experience, and how much is the result of subsequent invention.

238 x-Q. Still, without going into details, I would like your opinion as an expert whether this ability to manufacture burners of a reduced diameter is in any measure dependent upon the subsequent inventions?

A. I think that it is to some extent.

239 x-Q. From various things contained in your testimony, I judge that you would also say that since the date of the patent in suit there has been a substantially constant effort on the part of the art to make carbon burners of *larger* crosss-section than it was practically possible to secure by the methods of manufacture known to the art during the period immediately succeeding the grant of the patent. Do you so hold?

A. Some time after the commercial introduction of the modern incandescent lamp commenced it was ascertained that there was use for similar lamps, with burners of large diameter. The art has succeeded by its efforts in constructing such lamps, with burners much larger in diameter than could be made immediately after the date of the patent.

240 x-Q. In your opinion as an expert, is this ability of the art to make burners of larger diameter also dependent measurably upon inventions subsequent to the date of the patent in suit?

A. I think so, to some extent.

241 x-Q. Do you know when first any of these subsequent inventions were made use of, whereby the art was enabled to produce burners that were smaller or burners that were larger than those which it was possible to produce by any of the methods known to the art immediately after the grant of the patent in suit?

A. I think that it was in the summer, possibly in the spring, of 1880.

242 x-Q. What particular invention or inventions do you now have in mind?

A. Mr. Edison's invention of a burner made from carbonized bamboo.

243 x-Q. You do not understand, do you, that this is the only invention subsequent to the date of the patent

in suit which has enabled the art to make carbon burners both smaller and larger than it was possible for the art to make by the methods known at the date of the patent?

A. That is the only invention which I had in mind. I know that burners are made from other carbonizable materials by processes invented since the date of the patent in suit which also make it possible to construct burners both larger and smaller than could be made immediately after the date of the patent.

Adjourned for lunch.

Resumed.

244 x-Q. Are you now able to state either the maximum or the minimum size of burner that it was practicable to make by the methods that were known to the art immediately after the grant of the patent in suit, and without the aid of these subsequent inventions which the art has since availed of in order to make still smaller and still larger burners?

A. That is a difficult question to answer, for the reason that some of these inventions were made soon after the date of the patent in suit, and advantage was at once taken of them in the practical construction of burners, and later on to increase and diminish their diameters, which became possible, not immediately upon the inventions being made, but only after experience and skill had been acquired. Under these circumstances it is difficult to state the smallest and largest diameters which might have been given to burners made according to the method described in the patent in suit, if the art had been obliged to depend wholly upon the skill acquired in working under the patent, and had not derived some advantage from subsequent improvements. In my opinion, the present ability of the art to construct burners of the largest and smallest diameters now in use has been in a much greater meas-

ure due to skill and experience than to inventions subsequent to the date of Edison's patent, and while these inventions have undoubtedly been of some advantage, still I think that without them the art would have been able to make burners approaching in size the largest and smallest now in use.

Adjourned to Sept. 3, at 11 A. M.

SEPTEMBER 3, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, C. L. CLARKE, CONTINUED:

245 x-Q. You have assumed that in the modern lamp, from the chamber of which not only air but other gases are excluded until a very high vacuum is attained, the evaporation or disintegration of the carbon is so slight that for this reason the modern lamp is essentially different from any of the old lamps, in which, you claim, there was present either a destructive amount of oxygen (owing to the imperfect exhaustion of the air), or of other gases of a deleterious nature, introduced as one mode of excluding the oxygen.

Now, is it not a fact that the comparative absence of evaporation of the carbon, which you assume to exist in the modern lamp, depends in large measure upon the way in which the lamp is used; and is it not a fact that by a slight increase in the amount of the current passed through the lamp (as shown by tables II. A IV., and V., and the connected diagrams, in Defendant's Exhibit "Siemens' Article"), the resistance of the lamp will increase rapidly, accompanied with a rapid falling off in efficiency and in stability and durability, so that in fact lamps which when run at 96 volts will last on an average more than 600 hours (running down in efficiency in that time some 31 per cent.), will run down in efficiency nearly one-half (to be more accurate, 46 per cent.) in 100 hours, if the current be put up to 115 volts, and will not last more than about eleven hours on an average, if the current be increased to 123 volts?

A. It is a fact that the tests made by Siemens show that lamps increase in resistance and diminish in efficiency, and that when the electro-motive force is increased above the amount for which the lamp is intended, the reduction in efficiency in a given time also increases, while the stability and durability diminish, as is shown by the results of the tests which were made upon 96-volt lamps, a summary of which is given in the question. While Siemens' tests (each made upon ten lamps) prove a general truth, I do not think that the results obtained can be relied upon as correctly representing the average result which would be obtained from testing a large number of lamps. I am unable to see from these tests, however, as might be inferred from the question, that the increase in resistance and decrease in efficiency are related to or are the cause of the shorter life of the burner.

246 x-Q. Independently of these tests of Siemens, is it not a well-established fact that the stability of a burner of a given lamp, or in other words the life of a lamp, depends upon the electro-motive force of the current used—to the extent that, with a current of very low electro-motive force, developing in the lamp a low incandescence, the lamp may be made to last several thousand hours, while by largely increasing the electro-motive force, so as to develop a very high incandescence, the carbon would not have sufficient stability to endure even for an hour.

A. Yes.

Adjourned for lunch.

Resumed.

247 x-Q. Do you find anything in the patent in suit instructing as to the electro-motive force necessary to

be used in order to render a given carbon sufficiently stable for practical use?

A. No, I do not find any specific directions upon this point. Neither do I think that it was necessary that the art should be instructed concerning the electro-motive force which should be used in order that the burner should be durable enough for commercial purposes. In my opinion the patent describes a method of making burners of widely varying resistance, extent of radiating surface and candle-power which may also require considerable difference of electro-motive force for their operation; and I believe that after the patent had instructed the art how to make such burners, which are stated to be stable at very high temperatures, the art would have recognized that lamps having such burners would have a commercial value, and would by testing them, determine the electro-motive force under which they should be operated,

248 x-Q. I understand you to admit that the *stability* or *durability* of an Edison incandescent lamp (using the term with reference to *practical* results) depends in very large measure upon the electro-motive force with which the lamp is run; also that the patent in suit gives no instructions as to the electro-motive force which is suited to lamps made under the patent. Under these circumstances, do you think it correct to claim, as might seem to be indicated in the patent, that the burner of the patented lamp is "absolutely stable?" In other words, so far as the superiority of the patented lamp depends upon the *stability* of the carbon, is not this a mere matter of degree; and even so is it not dependent largely upon conditions not set forth in the patent?

A. Understanding that I am in reality asked to answer the last sentence of the question, I do not think that, considered from a practical standpoint, the stability of a burner made according to the patent is a question of degree, when compared with the length of time the burners of old lamps would last, which, as I understand it, had *practically no durability*; and neither do I think that the stability of a burner made according to the patent was at all dependent upon conditions not set forth in the patent which the art was not already familiar with, and which it would not at once apply without farther instructions or additional invention. On the contrary, the stability of the burner was in the main due to the new condition under which it was operated, that is to say, in a very high vacuum.

Adjourned to September 4, 1890, at 11 A. M.

SEPTEMBER 4, 1890.

Met pursuant to adjournment.

Present—R. N. DYER, of counsel for complainant; S. A. DUNCAN, of counsel for defendant.

CROSS-XEAMINATION (continued):

249 x-Q. Will you explain what you mean by the expression just used by you, and which frequently occurs in your testimony, viz.: "a very high vacuum"; and, particularly, please state whether the improvement of the vacuum up to the highest attainable point is accompanied with a corresponding improvement in the lamp?

A. I mean a vacuum so high that the lamp shall be durable enough to make it of commercial value. I do not understand that a lamp improves in durability and efficiency in a measure corresponding to the perfection of the vacuum up to the highest attainable limit.

250 x-Q. Omiting consideration of the *rate* of improvement, do you understand the fact to be that the lamp continues to increase in durability and efficiency, or in either respect, as the vaucum is increased; or, on the other hand, is it a fact that as you increase the vacuum beyond a certain point, the durability or efficiency of the lamp diminishes?

A. All I can say concerning any degree of vacuum which is too low is that the lack of durability and efficiency taken together prevent the lamp from having any practical value. With any degree of vacuum higher

than this which it is practically possible to obtain, the lamps, I understand, are commercially durable and efficient.

251 x-Q. What I wish to know is this: Whether, when you have obtained the lowest vacuum that will give you a practically durable carbon, any increase in such a vacuum will be attended with an increase in either the durability or the efficiency of the carbon, and, if so, whether that improvement in the lamp continues as you continue to increase the vacuum up to the highest attainable point of the latter?

A. I believe that the result is to increase the durability and efficiency of the lamp up to the highest practically attainable vacuum, but not in a degree corresponding to the perfection of the vacuum.

252 x-Q. Would this be equally true when the residual gas of the vacuum is atmospheric air, and when it is one of the so-called "inert" gases, such, for instance, as nitrogen?

A. I think so, although I cannot call to mind any experiments made to prove it.

253 x-Q. Which size of carbon burner will admit, consistently with practical durability, of the employment of the lower vacuum—a large carbon (such, for instance, as is employed in the Edison 100-candle power new lamp) or a small carbon (such, for instance, as is used in the Edison 16-candle power lamp)?

A. I think the larger carbon of the 100-candle power lamp.

254 x-Q. Why?

A. For the following reasons. With the lower vacuum (no lower than is consistent with practical durability and economy) heat is more rapidly taken away from the burner by convection and conduction, due to the greater amount of gas present, resulting in the necessity of increasing the strength of current and amount of heat supplied to the burner, in order to bring it up to its proper temperature and candle-power. Under these conditions the larger burner appears to have more mechanical stability to withstand the increased current and heat than the smaller burner.

255 x-Q. If, for the reason just given by you, a comparatively large carbon will have more mechanical stability than the smaller one, so as to admit of the employment of a lower vacuum without practical impairment of the durability of the lamp, will it not follow that with the same vacuum the larger carbon should have greater capacity to withstand the current and the heat than the small one?

A. I did not say that there would be no change or impairment of the durability of the lamp with the lower vacuum. What I did say amounts to this, that if the vacuum were lowered, the larger carbon, when used in this vacuum, would have more durability than the smaller carbon when used in the same vacuum. Both carbons would, in my opinion, have their durability diminished by use in the lower vacuum, but I assumed that the vacuum should not be so low as to diminish the durability to such an extent as to make the lamps impracticable. As a matter of fact, I believe that while the art has become able to make burners varying considerably in diameter, which at a given temperature and degree of vacuum have on the average the same durability it is understood, as the outcome of practical experience with modern incandescent lamps, that, while a lowering of the vacuum diminishes the durability as well as the economy of lamps with all sizes of burners, the effect is greater upon the smaller sizes.

256 x-Q. Referring back to 251 x-Q. and your answer thereto, is it not also a fact that as you diminish the vacuum of a lamp from the lowest vacuum that will give a practically or commercially durable carbon, you will diminish the durability of the lamp, and that such deterioration of the lamp, attendant upon the diminution of the vacuum, will continue until the lamp is wholly worthless?

A. Since the date of the patent in suit it has been ascertained that by diminishing the vacuum to a sufficient extent, the durability and efficiency of a lamp which with a high vacuum would be of commercial value can be not only so greatly impaired as to result in its having no commercial value, but even to the extent that it will have a very short life.

257 x-Q. What is the lowest vacuum that can be used in a lamp and leave the carbon sufficiently stable for practical use?

Objected to as immaterial.

A. I do not know.

258 x-Q. Then as to this branch of this controversy you would not regard yourself, I suppose, as an expert?

A. I will let my qualification as an expert given in answer to 2 Q. speak for itself on the whole subject involved in this deposition. As to the particular matter inquired of in 257 x-Q. I will say that, although I do not know the lowest degree of vacuum which it is possible to use and yet have a practically commercial lamp, I do know the vacuum used in lamps made by the Edison Company, which, I think, does not vary greatly from that used by other lamp manufacturers.

259 x-Q. What is that vacuum?

A. About one thirty-thousandth ($\frac{1}{30,000}$) of an atmosphere.

260 x-Q. Do you know what is the highest vacuum obtainable by the Torricellian method as at present practised?

Objected to as immaterial.

A. With a simple barometer tube a very high vacuum can be obtained, but I am unable to state the extreme limit.

261 x-Q. Can a vacuum be obtained by this method as high as the one thirty-thousandth ($\frac{1}{30,000}$) of an atmosphere?

A. I think so.

Adjourned until September 5, 1890, at 11 A. M.

SEPTEMBER 5, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, C. L. CLARK, CONTINUED:

262 x-Q. How long has this been possible.

A. That I cannot state definitely, but I think that it has been known how to obtain a very high vacuum in a simple barometer tube for many years.

263 x-Q. With a piston air-pump how high a vacuum can be obtained?

A. That I cannot state definitely, but I think that it will be very low as compared with the vacuum obtained in a barometer tube by the Torricellian method.

264 x-Q. I find in Faraday's "Experimental Researches in Electricity," published in 1834 (on page 250, Vol. I., of the reprint of 1839), the following statement:

> "The same quantity of electricity which, passed in a given time, can heat an inch of platina wire of a certain diameter redhot can also heat a hundred, a thousand, or any length of the same wire to the same degree, provided the cooling circumstances are the same for every part in all cases."

Do you understand this statement of Faraday to be true?

A. Yes, but it should also be borne in mind that the electro-motive force necessary to cause the electricity to flow through the wire will increase with its length.

265 x-Q. Would this statement of Faraday's be equally true whether the hundred or thousand inches of wire were continuous in one length or divided up into a hundred or a thousand separate pieces, assuming in the latter case that the separate parts are connected by conductors of such small resistance as to be practically negligible?

A. Understanding that the pieces are to be connected in series, the statement is also true in this case, although a greater amount of energy would be required if the wire is divided into short lengths than if in one continuous piece, because the large intermediate connecting wires would conduct heat away from the platinum wires at their numerous points of connection.

266 x-Q. Do you not think that long prior to 1879 a person skilled in electrical matters would have understood perfectly well that, by proportionately increasing the electro-motive force of an electric-lighting circuit as new lights were added to the circuit, one could keep all the lamps at a constant illuminating power, and thus with a constant amount of current produce the same amount of light at each one of several foci as originally he would have obtained from one lamp only?

> Objected to as not proper cross-examination as to which the defendant makes the witness its own.

A. Leaving out of consideration those characteristics which prevented electric lamps from being practically operated when connected in series, it was, long prior to 1879, understood as a general proposition that the electro-motive force (or, as it was then termed, "intensity") of the current should be increased as lamps were added to the circuit.

267 x-Q. Was not a recognition of this principle essential to the commercial subdivision of the electric light?

A. I do not think so. As a matter of fact subdivision was not accomplished by arranging lamps in series, but in multiple arc. I think that it was necessary to know that as the resistance of an incandescent burner was increased by increasing its length the electro-motive force should be increased in the same proportion.

268 x-Q. Was it not also necessary to know that as *the number of lamps* was increased the electro-motive force should be correspondingly increased?

Adjourned for lunch.

Resumed.

A. Understanding that it is assumed that the lamps are arranged in series, I answer no. The problem of subdivision was accomplished by arranging the lamps, not in series, but in multiple arc, and an increase in the number of lamps connected to a circuit in the latter way does not call for an increase in the electro-motive force.

269 x-Q. I do not understand your position at all. By former parts of your testimony I understand you to have taken the ground that if fifty, or even a smaller number of lamps, had been arranged in series in a single building, and those lamps were so constructed as to be durable, such construction and arrangement of lamps would have been a practical solution of the problem of the subdivision of the electric light. I also understand that at the present time a very considerable part of incandescent lighting is accomplished by the use of lamps in series. Now, was it not necessary in effecting the subdivision of the electric light by the use of lamps arranged in series, to know that as the number of lamps was increased the electro-motive force of the current should be correspondingly increased?

Objected to as immaterial, indefinite and illogical, and also as misstating and confusing the facts and the testimony already given by the witness; the witness having testified that the problem of subdivision was accomplished by a multiple arc arrangement of lamps, and not by a series arrangement, the assumption of the question that the problem was accomplished by a series arrangement is directly contrary to the accepted fact, and any answer of the witness based upon such a false assumption can be of no benefit to the case. Counsel for complainant feels it his duty to again protest against the further protraction of the cross-examination by questions of this character.

Defendant's counsel states that he has not assumed that historically the problem of the

subdivision of the electric light was solved by the arrangement of incandescent lamps in series; but his question is designed to refer only to those instances of subdivision (which he understands are numerous) in which the lamps are put *in series.* He desires, however, to state that he does not accept the declaration of complainant's counsel to the effect that the problem of subdivision was in fact accomplished by a multiple-arc arrangement of lamps. This position seems inconsistent with the testimony of the witness, in his answers to 90–92 x-Qs. (in which he has, in effect, said that the problem would have been solved by the making, by the process described in the Edison patent, of a *single* lamp, irrespective of *the candle power of the lamp*, and *irrespective of the resistance* and of *the size and the proportions of the burner*) and with the fact, as shown by the proofs herein, that Mr. Edison professes to have ascertained the practical durability of a carbon burner by tests which he made with a single lamp only, being the first one that he made.

Counsel for complainant replies that counsel for defendant still confuses the historical *fact* as to how subdivision was accomplished with his *assumptions* contrary to the fact which formed the foundation of the answers of the witness referred to. Defendant's counsel, after having repeatedly made the same assumption, and having as often been told by the witness that the assumption is incorrect, seems unable to distinguish between that assumption and the established and accepted facts.

A. In answer to 71 x-Q., which I understand is referred to in the question, I stated that if fifty lamps of 96 to 160 candle power (assumed to be practically durable) were connected only in series, and if their construction had been such as would have instructed the art how to construct similar 16 candle-power lamps, of which a sufficient number could be operated in multiple arc on a single circuit so as to give the same total amount of light as the fifty large lamps, and with the same economy, this would, in my opinion, be regarded as accomplishing the problem of subdivision. Now, if fifty large lamps of the character above described, and arranged in series, had been the first practical lamps which were made, a certain electro-motive force would have been necessary to operate them, and it would have been known that any change in the number of these lamps in series would call for a corresponding change in the electro-motive force. But I fail to see what bearing this knowledge would have upon the question of subdivision, inasmuch as it relates only to the number of lamps arranged in series, each of 96 to 160 candle-power, while to accomplish subdivision the lamps should, in my opinion, be of about 16 candle-power, and arranged in multiple arc. I cannot agree with the statement in the question as to the amount of incandescent lighting now done by means of lamps arranged in series, understanding as I do that it is quite insignificant as compared with multiple arc lighting.

Replying to the last sentence of the question and, for the moment, adopting your assumption without admitting its correctness, I think it was essential to know how to construct durable and economical lamps adapted for use in series, which should possess such characteristics as would permit the construction of similar lamps of low illuminating power which, when arranged in series, would require the same total current and electro-motive force as a smaller number of lamps of high illuminating power, the total amount of illumination and power required being the same in both cases.

Adjourned until September 6, 1890, at 11 A.M.

SEPTEMBER 6, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, CHAS. L. CLARKE, CONTINUED:

270 x-Q. I will ask you to read carefully the last sentence of my former question, and see if you cannot answer it more directly.

A. Bearing in mind that subdivision was not accomplished with the lamps arranged in series, and that in my opinion it would not have been considered as accomplished until a method of constructing practical lamps adapted for use in multiple arc had been devised, and in addition, assuming that a method of making a practical lamp adapted for use in series, with an illuminating power about equal to a gas jet, were known, it would be necessary, in order that a number of these lamps might be operated in series, for the art to know that, as lamps were added to the circuit, the electro-motive force should be correspondingly increased. It has for many years been known that as the number of translating devices arranged in a circuit in series is increased, the electro-motive force must be increased in the same proportion. In my previous answer I had in mind what I believe was the fact, that prior to the date of the patent in suit carbon lamps, when operated under what was assumed to be normal conditions, were of very high illuminating power. Now, if several of such lamps were arranged in series, they would require a given electro-motive force and current to raise them to their normal illuminating power; and I considered that subdivision in series would have required the construction of other lamps about equal to an ordinary gas jet, and otherwise so constructed that when a sufficient number of them were arranged in series, they would produce the same total amount of light as the smaller number of lamps of high illuminating power, and the total electro-motive force and strength of current in both cases would be the same.

271 x-Q. Both you and the counsel for the complainant seem to me to go out of your way to emphasize the assumed fact that the problem of the subdivision of the electric light was solved only by the arrangement of incandescent lamps in *multiple arc*, as contradistinguished from their arrangement *in series*?

What is the warrant for this assumption? I ask the question especially in view of your own statement (as contained in your answers to 90-92 x-Q.s) to the effect that the problem would have been solved by the making and testing by the process set forth in the Edison patent, of a *single* lamp, *whatever the candle-power of such lamp*, and *whatever the resistance and the size and proportions of the burner;* and also in view of the fact (as shown by the proofs in this case) that the practical durability of a carbon lamp under proper condition of vacuum was ascertained by Mr. Edison by tests which he made with a *single lamp only.*

In other words, I would like to know whether you consider that Mr. Edison (to whom apparently you attribute the solution of the problem of subdivision) had solved the problem when he had made and tested that first lamp, or only after he had made a large number and had arranged and tested them in multiple arc?

A. I think that when Mr. Edison made the invention described in the patent in suit, and made a single lamp by the process therein set forth, and proved it to be durable, that was a solution of the problem of subdivision, for reasons given in my answer to 90 x-Q.

Adjourned until Monday, September 8, 1890, at 11 A. M.

SEPTEMBER 8, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS CHAS. L. CLARKE CONTINUED:

Answer to 271 x-Q. continued.

In answering the question, which I considered was virtually contained in the last sentence, I overlooked the fact that an essentially different question preceded this, to which I reply as follows: My warrant for the assumption that the problem of subdivision was solved by arranging the lamps in multiple arc, as contradistinguished from their arrangement in series, is based upon the historical fact that after the invention of the lamp made by the process described in the patent in suit, Mr. Edison and others first made such lamps, adapted for use in multiple arc, which have been used commercially in large numbers, and with which to-day by far the greater part of incandescent lighting is done. It was not until after lighting by means of lamps arranged in multiple arc had come into extensive use that lighting by means of incandescent lamps arranged in series was taken up. The amount of lighting done with series lamps is relatively small, and the use of such lamps has a limited application.

272 x-Q. What, approximately, is the ratio between lamps arranged in multiple and lamps arranged in series?

A. I cannot say exactly; but I hardly think that even five per cent. of all the lamps in use are series lamps.

273 x-Q. Do you not hold that the problem of the subdivision of the electric light was solved by the invention covered by the patent in suit? And do you not also hold that the invention which is covered by said patent is an incandescent *lamp*, and not any particular *mode of arranging* the lamps in a circuit?

The second branch of the question objected to as incompetent.

A. In my opinion the invention described in the patent in suit solved the problem of subdivision, because it instructed the art how to make lamps adapted for use in multiple arc, and also possessing other characteristic advantages which I have hereinbefore mentioned. I do not think that it was necessary, in order to solve the problem, that the patent should instruct the art how to make lamps adapted for use in series, although as a matter of fact, the patent did give such instructions to the art. As I look at it, the invention covered by the patent is for an incandescent lamp possessing characteristics which make such lamps eminently adapted for use in multiple arc.

Adjourned for lunch.

Resumed.

274 x-Q. In other words, as I understand you, the patent in suit is a patent for a lamp which, in addition to the "other characteristic advantages" to which you refer, has sufficiently high resistance to make it capable of use in multiple arc. Is this what you mean?

> Objected to as incompetent and not proper on cross-examination, the witness not having been asked upon direct examination to construe the patent. Complainant's counsel gives notice to defendant's counsel that if he insists upon the question he makes the witness his own.

A. No. In my opinion the invention covered by the patent is for an incandescent lamp having certain characteristics which are applicable to the construction of similar lamps, in such a manner as to adapt them for use in multiple arc.

275 x-Q. Do you mean, then, to say or to intimate that in your opinion, the lamp covered by the patent in suit does not necessarily have such a resistance as would make it capable of use in multiple arc?

> Same objection and notice.

A. In my opinion the patent is not necessarily limited to lamps having a resistance high enough to make them suitable for practical use in multiple arc.

Adjourned to September 9, 1890, at 11 A. M.

SEPTEMBER 9, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

276 x-Q. I suppose, then, that you would hold that the term "filament" found in the claims of the patent, has no necessary relation to the construction of a lamp for use in *multiple arc*?

> Same objection and notice.

A. Whatever relation the term "filament," found in the claims, may or may not bear to the construction of a lamp for use in multiple arc is a question which calls for the expression of an opinion upon the technical limitations of the invention as construed by the language of the patent. I have not been asked by the complainant to consider the patent in the suit, excepting as to the description of the lamp and the process of making it, and have not heretofore expressed, or intended to express, an opinion upon the technical limitations of the patent in my deposition, understanding as I do that the matter inquired of in the question and its limitations are properly only for the consideration of the Court. Under these circumstances, I do not feel called upon to express an opinion in answer to the question, and must decline to do so.

277 x-Q. Practically in the shops, and also in the literature of the art, is not the term "filament" applied indifferently to the carbon burners of incandescent lamps, both those which are designed for use in series,

and those which are designed for use in the multiple arc?

A. Yes.

278 x-Q. Was this term "filament" known to the art of incandescent lighting prior to the year 1879?

A. Not that I know of. I think that the term was first used in the patent in suit.

279 x-Q. When you say that in the shops the term is applied to lamps built for series work, as well as to lamps for multiple-arc work, I presume that you make no exception of the Edison Company's shops?

A. No.

280 x-Q. Assuming this term "filament" to have been new to the art at the date of the issue of the patent in suit, do you know of any way in which I can ascertain its meaning otherwise than by resort to the shops where the lamps are made, and to the literature of the art?

A. Aside from the shops and the literature of the art I will refer to the patent in suit, which describes a method of making incandescent lamps with burners which are stated to be "filamentary." As to the meaning of the term "filament," as limited by any technical construction of the patent, I must decline to express an opinion upon this point, for substantially the reasons given in my answer to 276 x-Q.

Adjourned for lunch.

Resumed.

281 x-Q. Do you know of any other way in which one can ascertain the technical meaning of this technical term "filament"?

> Objected to as incompetent if the technical *legal* meaning is inquired for; if the meaning applied by the art to this term is asked, the question has been answered by 277 x-A.

A. Besides the shops and the literature of the art of modern incandescent lighting, and the patent in suit, I will also refer to the exhibits and the depositions of the experts given in this case for both complainant and defendant for what they are worth. But I must decline to express an opinion concerning the technical meaning which the above mentioned-references put upon the term "filament."

282 x-Q. Do you yourself know, or do you think that you know, the meaning of this new term "filament," which, as I understand you, makes its first appearance in the art of electric lighting in the patent in suit?

> Same objection.

A. Not having been called upon in this case to consider the meaning of the term "filament" as construed by the patent, I have no opinion to express as to what constitutes a filament as technically defined therein.

283 x-Q. I did not ask you to express an opinion as to what constitutes "a filament as technically defined therein" (the patent in suit), well remembering that you had already declined to express such opinion; but what I asked you in my last question was whether you know, or think you know, what that thing is which is spoken of in the patent (for the first time, as you assert, in the art of electric lighting) as a "filament." This question you did not answer. Please do so.

> Same objection.

A. Inasmuch as I have already declined to express an opinion, as I believe for good and sufficient reasons, as to the technical meaning of the term "filament" made use of in the patent, I fail to see what advantage can be derived from merely knowing the fact as to whether I have formed an opinion upon this point or not. With due respect to counsel for defendant, I do not think that the question is a proper one to ask and I decline to answer it, unless advised by complainant's counsel, or instructed by the Court so to do.

Adjourned until September 10th, 1890, at 11 A. M.

Sept. 10th, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

284 x-Q. Has complainant's counsel told you within the past twenty-four hours that you ought to be "very shy about going into the patent," meaning the patent in suit?

> Complainant's counsel in reply to the question states that he has, as defendant's counsel is well aware, and in the presence of defendant's counsel, and as he understood, with the consent of defendant's counsel, supplemented his objections of record to the questions calling upon the witness to construe the patent in suit, with the remark referred to in the question, and perhaps other similar remarks.
>
> Defendant's counsel states in reply that the remarks admitted by complainant's counsel to have been made by him have occurred substantially during the last two days; the particular remark above quoted being made, as defendant's counsel recalls, immediately after the asking of 275 x-Q. With reference to the said remark defendant's counsel stated in the presence of the witness and of complainant's counsel that, while he thought that properly it ought to go down on the record, he cared nothing about it and should not ask to have it go down on the record, unless the witness refused to answer his questions. As the witness now refuses to answer, upon the alleged ground that he (the witness) cannot see the importance of the question, defendant's counsel thinks that the record should show what the real facts in the matter are.

Answer waived in view of the statement by complainant's counsel.

285 x-Q. Please explain what you mean by the term "technical" in your answer to 283 x-Q., where you say that you have "declined to express an opinion as to the *technical* meaning of the term filament made use of in the patent."

A. I mean that definition which would be given to the term "filament" used in the claims, as defined by the language of the specification.

286 x-Q. Then, as I understand you, you did not by that form of expression intend to refer to the meaning which is attached to the word "filament" in the art of electric lighting?

A. No, I had only the patent in mind.

287 x-Q. In your testimony heretofore, as I recall, you have repeatedly used the word "filament," or some of its derivatives. In so doing it did you intend to use it in a meaning different from that which attaches to it in the patent in suit?

A. I cannot now recall the particular circumstances which may have led me to make use of this term, but wherever I may have done so, I made use of it either in the sense in which it is used to-day, as applied to *all* burners of modern incandescent lamps, or as applied to burners made by the process described in the specification of the patent in suit.

288 x-Q. So far as you know, are not the burners of *all* the incandescent lamps of the present day made by "the process described in the specification of the patent in suit;" and if so, does the distinction which your last answer seems to draw between two different kinds of burners really exist?

A. So far as I know, the burners of all commercial incandescent lamps are made by the process described in the specification of the patent. I did not in the last answer intend to imply that there was any difference in the process of making these burners.

289 x-Q. Then in the said answer you meant to say in substance that, whenever you have used the term "filament" in this deposition, you used it in the sense in which it is used in the art, as applied to all incandescent lamps?

A. I think so, understanding that in its modern sense the term "filament," as used in the art of electric lighting, is now synonymous with the word "burner." I might, therefore, with equal propriety have used the latter term.

290 x-Q. Do you assert that in the "modern sense," in the art of incandescent lighting, the term "filament" is synonymous with "burner"?

A. If I am asked whether the art to-day makes use of both of these terms in giving a name to the thing which is heated by the current and produces light, I answer yes.

291 x-Q. Does the art regard these terms as *synonymous?*

A. Yes.

Adjourned for lunch.

Resumed.

292 x-Q. Do you know of any time since the 27th of January, 1880, when the art did not regard these two terms as synonymous?

A. No, I believe that the terms "filament" and "burner" have been used indifferently by the art to designate the incandescent conductor of modern lamps since the date mentioned in the question.

293 x-Q. In your answer to 289 x-Q. you say that you might with equal propriety have used the term "burner" in your deposition wherever you have in fact used the term "filament." I suppose, therefore, that the last sentence of your answer to 13 Q. is to be understood as it would be if the word "burner" were substituted for the word "filament"?

A. Yes.

294 x-Q. In what sense did you use the term "filamentary" in the concluding sentence of your answer to 12 Q.

A. In the sense in which it is ordinarily used and defined in the dictionaries, namely, as referring to a "thread-like" form.

295 x-Q. The definition which Webster gives of "filamentary" is: "Having the character of or formed by a filament." When you used the term "filamentary" in your answer to 12 Q. did you use it in this sense?

A. Yes, with the understanding that the meaning of the word "filament" is to be taken in the sense in which it is defined in Webster's Dictionary as being a "thread or thread-like object."

296 x-Q. By this answer do you wish to be understood as intimating that you used the term "filamentary" in 12 Ans. for the purpose of drawing a distinction between different sizes of such burners as are usable in different sizes of commercial incandescent lamps?

A. I did not have in mind burners of different sizes, or of any one particular size, so long as they were "thread-like."

297 x-Q. But did you not intend by the use of that term to distinguish between those burners to which you would now apply the term "thread-like" and burners of a different size?

A. I had in mind burners which were thread-like, and the carbon rods used in lamps prior to the date of the patent in suit.

Adjourned to September 11, 1890, at 11 A. M.

SEPTEMBER 11, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS CHAS. L. CLARKE CONTINUED:

298 x-Q. As I understand you, when you used the term "filamentary" in your answer to Q. 12, you had in mind burners that were "thread-like," and intended by the use of the term to draw a distinction between *such* burners and the carbon burners, which you designate by the term "rods," of the lamps which preceded Mr. Edison's work. Does this correctly represent you?

A. Yes.

299 x-Q. How small must a carbon be in order to be "filamentary" (or "thread-like"), as you used this term; or, in other words, how large must a carbon be before

this term would cease to be applicable to it, assuming the term used in the sense in which you profess to have used it in your testimony?

A. I cannot state in the abstract what size a body should have in order that it should cease to be a thread and become a rod or something else. In speaking of the burners of incandescent lamps as being thread-like, I had in mind the burners of incandescent lamps which have been most commonly made and used in multiple arc for commercial lighting since the date of the patent in suit.

300 x-Q. The qualifying words "most commonly," found in your last answer, lead me to think that you do not consider the burners of *all* commercial incandescent lamps as "thread-like," and therefore that you do not regard them all as "filamentary;" is such the fact?

A. I hardly know whether the largest burners used in commercial lamps can be called "thread-like" in the ordinary acceptation of that term, but I should hardly call them such myself.

301 x-Q. In other words, you do not regard them as "filamentary" as you have used that term in your present examination?

A. As I have already stated, when I used the word "filamentary" in my answer to 12 Q., I had in mind only the burners of lamps which have been most commonly used since the date of the patent in suit, and did not intend that it should apply to the burners of any other lamps. As to whether I have used this term elsewhere in my deposition in any other sense or not, I shall be pleased to state if the particular instances of its use referred to in the question are pointed out to me.

302 x-Q. I understand the statement of your last answer to be tantamount to a declaration that you did not use the word "filamentary" in your answer to 12 Q. as embracing *all* sizes of thread-like carbons, but only as relating to some of the smaller sizes of such carbons. Am I right in this interpretation of your last answer?

A. Yes.

Adjourned for lunch.

Resumed.

Answer continued.

Upon consideration, the answer which I have already given to this question may, I think, lead to some misunderstanding as to my use of the term "filamentary," to avoid which I wish to say that I used the term as being synonymous with "thread-like." If the present question refers to carbons which I consider to be thread-like, some of which are smaller than others, then I answer that, in using the word "filamentary," I did not intend to include some which were thread-like and to exclude others.

303 x-Q. Then, when you used that word "filamentary," you intended to refer to *all* of the various sizes of burners in practical use to which, in your judgment, the other term "thread-like" would be applicable, at the same time understanding that there are *some* sizes of burners in use to which the term would not be applicable. Is this correct?

A. I intended to refer to the various sizes of burners of lamps which have been most commonly used in multiple arc, because I considered them to be filamentary or thread-like. I did not have larger burners than these in mind, because I considered it an open question whether they could be properly called "thread-like" or not, while the very largest sizes should, in my opinion, be classified as "rods," although they would be small as compared with the rods of old lamps.

304 x-Q. By the use of that term "filamentary" (in answer to 12 Q.), you were drawing the distinction, were you not, between those burners which you regarded as "thread-like" and those to which, in your opinion, this term would not properly apply?

A. Not exactly. I had in mind burners which were, in my opinion, "thread-like;" others which were "rods," and intermediate sizes which might be classed as "doubtful."

305 x-Q. Is *this* the fact, then, that in using the term "filamentary," in 12 A., you were drawing a distinction between those sizes of burners which you regarded as "thread-like" and *both* those which you regarded as

"rods" *and* those which occupied an intermediate ground, and as to which you were in doubt whether more properly they should be called "thread-like" or "rods"?

A. I did intend to make a distinction between those burners, which I thought were undoubtedly thread-like, and all others. I used the term "filamentary," however, as being synonomous with "thread-like."

Adjourned until Saturday, September 13, 1890, at 11 A. M.

SEPTEMBER 13, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

306 x-Q. Inasmuch then as you used the term "filamentary" as characterizing those burners *only* which you regarded as "thread-like," and not as including all sizes of burners in practical use in commercial lamps, will you please explain the difference between burners which are "thread-like" and those to which this term does not apply.

A. I think that burners small in diameter would be "thread-like," and that this term would not apply to burners large in diameter.

307 x-Q. What is the standard which determines whether a burner be "large" or "small," as you have now used these terms?

A. The carbon burners used in the old lamps.

308 x-Q. If that be the standard, why don't you include *all* sizes of burners in use in modern lamps under the term "thread-like" or "filamentary," since, as you claim, *all* of these burners are materially smaller than the burners of the old lamps?

A. The lamps which have been most commonly used in multiple arc and which have given value to modern

incandescent lighting have burners very much smaller in diameter, when compared with the burners of the old lamps; while on the other hand some modern lamps have burners more or less approaching the size of the smallest burner used in any of the old lamps of which I have knowledge, and which are only suitable for use in series, and have a very limited application. In view of these facts it seems to me entirely appropriate that of all the modern incandescent lamps I should consider those first above mentioned as "small," and those last mentioned as "large."

309 x-Q. Do you mean by this to say that those burners that are adapted for use in multiple arc are "small," and therefore "thread-like" or "filamentary," as you have used these terms, while those that are only suitable for use in series are "large," and therefore not "thread-like" or "filamentary?"

A. Not exactly. I think that the burners of some lamps which are adapted for use only in series are small enough to be called "thread-like," but burners of the same diameter can be made suitable for use in multiple arc. And on the other hand there may be burners not "thread-like" which are made so as to be suitable for use in multiple arc.

310 x-Q. If the capacity of being used in multiple arc on the one hand, or in series on the other, is not the thing that in your mind distinguishes a "small" carbon from a "large" carbon, what is the distinction between these two classes of carbons?

A. Those burners which I deem to be "thread-like" are small, and are represented in the burners of lamps which have been most commonly used in multiple arc. Now, I believe that, as compared with these, the burners used in lamps prior to the date of the patent in suit were *relatively* large; and because burners as large as these would under no circumstances be suitable for use except in series, I feel warranted in considering that the largest burners of modern lamps (not greatly smaller and likewise suitable for use only in series) are also relatively "large," as compared with those most commonly used in multiple arc. I do not think that the question as to whether a burner is in reality "large" or "small" is dependent upon the fact that it can be made suitable for use in series or in multiple arc, but is dependent upon its size.

Adjourned until September 15th, 1890, at 11 A. M.

SEPTEMBER, 15th, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS CHARLES L. CLARKE CONTINUED.

311 x-Q. In your last answer you say that the largest burners used in modern lamps are "*relatively* large as compared with those most commonly used in multiple arc." Did you mean by this, taken with its context, to indicate that such burners are "large" in the sense in which you have used this latter term in your answer to 306 x-Q, where you use it in the sense of *not "thread-like?"*

A. Yes, understanding that in both cases I had in mind not only their relative but also their actual size.

312 x-Q. Now, please explain why you regard the burners of the lamps which are most commonly used as "thread-like" or "filamentary," and the burners of other commercial lamps as not "thread-like." Is the difference one of size merely?

A. Understanding that I consider burners to be "thread-like" because they are small, and that the question refers to lamps most commonly used in multiple arc and to other commercial lamps having the largest sizes of burners, and considering these burners as things, I think that the difference is one of size merely.

313 x-Q. Inasmuch then as the difference between those burners which you regard as "thread-like" or "filamentary" and those which are not "thread-like" is one of size merely, please explain why you regard the

smaller of the burners of modern lamps as "thread-like," and why you do not regard the larger ones as "thread-like?"

Objected to as having been repeatedly asked and answered.

A. Simply because I think some burners are small enough to be called thread-like, while others are so large that this term cannot properly be applied to them.

314 x-Q. What is the difference in size between a burner which is "thread-like" and one which is not "thread-like?"

A. I cannot state definitely how large a burner should be in order that it should cease to be thread-like, although in my opinion the term is properly applicable to the burners of all commercial lamps made by the Edison Company.

315 x-Q. What lamp is there made commercially whose burner is not "thread-like?"

A. I think that some of the lamps made by the Thomson-Houston Electric Company cannot be properly considered as "thread-like." I am under the impression that some of the largest burners used in Heissler & Bernstein series-lamps are too large to come within this definition, although I admit that I have no exact data relating to the dimensions of the burners last mentioned.

316 x-Q. What is the difference in size between the Thomson-Houston burners to which you now refer and the largest burner of the Edison lamps?

Adjourned for lunch.

Resumed.

A. The smallest of the Thomson-Houston burners which I had in mind is one and fifteen hundredths (1.15) times thicker and one and nine-tenths (1.9) times wider than the largest Edison burner, and the area of the cross section of the former is two and fifteen hundredths (2.15) times that of the latter.

The Thomson-Houston burner is 0.04059 of an inch wide and 0.017 of an inch thick, giving an area in cross section of 0.00069003 of a square inch. The Edison burner is 0.0217 of an inch wide and 0.0148 of an inch thick, giving an area in cross section of 0.00032116 of a square inch.

317 x-Q. Are there other Thomson-Houston burners whose cross section is larger than that of the Edison burner just referred to, but smaller than that of the Thomson-Houston burner just referred to?

A. Yes.

318 x-Q. What are their cross-sections?

A. There are eight different sizes of Thomson-Houston burners used in fifteen different types of lamps, the the area of whose cross-section lies between the Edison and Thomson-Houston burners referred to in the last question. The area of the cross section of the largest is 0.0005932095 of a square inch, and that of the smallest is 0.000345876 of a square inch.

319 x-Q. Why do you regard an Edison burner the cross-section of which has an area of 0.00032116 of an inch as "thread-like," and the Thomson-Houston burner having a cross-section of 0.0003458 6 of an inch as not "thread-like"?

A. I did not know that I had said anything that would lead one to suppose that I consider one of these burners as thread-like and the other as not thread-like. My position is this: I think the largest Edison burner is small enough to be called thread-like, and that this definition would not property apply to the largest of the Thomson-Houston burners, one of which—the smallest of the lot which I had in mind, is referred to in my answer to 316 x-Q. If we assume that the difference or dividing line between a thing which is thread-like and a rod is discoverable, I think that its position will be very much nearer to the size of the largest Edison burner than to the size of the Thomson-Houston burner above-mentioned, although I am really unable

to form an opinion as to where a thread-like body ends and a rod begins.

320 x-Q. You say, "*If* we assume that the dividing-line between a thing which is *thread-like* and a *rod* is discoverable," you think it would lie between the two points named. By this, do you mean to suggest that the dividing line is not discoverable?

A. No. Consensus of opinion might result, I think, in definitely locating a dividing line, or at least in reducing the doubtful region to quite narrow limits. But I do not see how there can be any doubt as to the proper definitions to give to burners like those made by the Edison Company, and to other burners approaching in size the rods used in the old lamps.

321 x-Q. Why do you hold, as in your last answer but one, that the largest Edison burner is small enough to be called "thread-like" (although in fact it is, I believe, more than twelve times the size of the burner used in the Edison 16-candle power lamp), while a Thomson-Houston burner, which you say is but a trifle more than twice as large as the largest Edison burner, is not "thread-like," but a "rod"?

A. Simply because the largest Edison burner appears to me to be small enough to be called thread-like, while the term, in my opinion, is not appropriate to the Thomson-Houston burner above referred to, although the latter is but twice the size of the former. To my mind the fact that the 16-candle-power burner has a cross-section about one-twelfth that of the largest Edison burner is of no significance. If a burner of a given size is small enough to be called thread-like, certainly burners smaller than this (no matter how many times smaller), also come under the same definition.

Answer objected to as not responsive.

322 x-Q. Where in the dictionaries, or in the literature of the art, or elsewhere, do you find warrant for a definition of the term "thread-like," which would make this word include a burner whose cross-section is 0.00032116 of a square inch (the size of the largest

Edison burner), and exclude a burner whose cross-section is two and fifteen-hundredths (2.15) times as great?

A. The definition of the term thread-like or filamentary taken in connection with the ordinary usage of these terms, and the fact that the smallest burners in the old lamps were called rods, is in my opinion a sufficient warrant for the distinction which I have made between these two sizes of burners.

323 x-Q. Where do you find a single authority justifying this last statement of yours?

A. I have used the term "thread-like" as being synonymous with "filamentary." The latter term is defined in Webster's Dictionary as "Having the character of, or formed by, a filament." A filament is defined as, "A thread, or thread-like object or appendage; a fibre; especially (Bot.), the thread-like part of the stamens supporting the anther." A thread is defined as, "A very small twist of flax, wool, cotton, silk, or other fibrous substance, drawn out to a considerable length." The term "thread-like" is not defined in this dictionary, but, as I understand it, is generally applied to those objects whose diameter is comparable to that of ordinary thread.

Adjourned to September 16, 1890, at 11 A. M.

SEPTEMBER 16, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS CHARLES L. CLARKE CONTINUED:

Answer to 323 x-Q. continued.

Worcester defines a body as "thread-like" when "resembling thread in size and appearance"; and the word "thready," which I take to be synonymous with "thread-like" is defined as "resembling thread; slender; filamentous; fibrous." According to the same authority a "thread" is "A small line or twist of any fibrous or filamentous substance, as flax, silk, cotton, or wool, particularly such as is used for weaving or for sewing; a filament; a small string."

In the light of these definitions, and as a matter of common sense, I think that the largest Edison burner may be properly called thread-like.

Now, from Higgs' translation of Fontaine's work on "Electric Lighting" I think it is evident that the author considered the burners which he mentions having used in his experiments on incandescent lighting, and which are stated to have been 0.062976 of an inch (0.0016 metre) in diameter, as "rods" for he several times refers to them as such. The width of the largest Edison carbon is approximately one-third ($\frac{1}{3}$), and its thickness one-fourth ($\frac{1}{4}$) of the diameter of Fontaine's rod, and the area of the cross-section of the former is nearly one-tenth ($\frac{1}{10}$) that of the latter: while, as compared with the same rod, the width and the thickness of the Thomson-Houston burner now under consideration are respectively two-thirds ($\frac{2}{3}$) and three-tenths ($\frac{3}{10}$) of this diameter, the area of the cross-section of the former being between one-fourth ($\frac{1}{4}$) and one-fifth ($\frac{1}{5}$) that of the latter. Taking into consideration the definition of the term "thread-like," in connection with what Fontaine terms a rod, and the fact that the difference in size between this rod and the Edison burner is considerably greater than the difference between it and the Thomson-Houston burner, I feel justified in considering the latter as being also a rod.

324 x-Q. Even if it be assumed that the burners used by Fontaine were "rods" (and not "thread-like"), I fail to understand how the definitions of "filament" and "thread" which you have quoted from the dictionaries justify you in the conclusion that a burner which is only one-fourth or one-fifth the size of the Fontaine burner is also, necessarily, a "rod," while a burner which is one-tenth the size of the Fontaine burner is

not a "rod", but is "thread-like." Please make this matter plain, if you can?

A. All I can say is that in the light of the dictionary definitions and my understanding of the general use of the terms "filament" and "thread" as defining "filamentary" and "thread-like", the Edison burner is small enough to be called "thread-like." On the other hand, burners like that mentioned by Fontaine are called "rods" (defined in Webster's dictionary as "a slender stick"). In my opinion the Thomson-Houston burner is likewise large enough to be considered a "small stick" and therefore a "rod."

Adjourned for lunch.

Resumed.

325 x-Q. Is the difference between the burners of the commercial incandescent lamps of the present day, by virtue of which, if I have understood you aright, you would classify some of them as "rods," and characterize others as "thread-like" or "filamentary," a difference in size only?

> Objected to as having been already asked and answered, and as intended only for delay.
>
> Defendant's counsel repudiates the last suggestion as unwarranted by anything which has occurred in the case; and adds by way of explanation of the question that in his own opinion he has heretofore asked a question of substantially the same tenor as the present one, but the indirect and qualified answer which the witness chose to make to that question leaves it doubtful in the questioner's mind as to what position complainant's counsel will take as to this branch of the testimony. The question, therefore, has been repeated in the hope that the witness may be able to find some form of statement that will put his views beyond all question.
>
> Complainant's counsel replies that as to this branch of the inquiry the witness is the defendant's witness, and not the complainant's witness, and that the opinions expressed by the witness may or may not represent the position complainant's counsel will take upon the argument of the case.
>
> Defendant's counsel states that he fails to see how he makes the witness his own on this question. On the direct testimony the witness in expressing his opinon upon matters inquired about by complainant's counsel, made use of the terms "filament" and "filamentary." Those opinions are not comprehensible except as these terms are understood. Defendant's counsel deems it entirely legitimate to learn from the witness himself in what sense these words were actually used—particularly in view of the fact that the word "filament," as stated by the witness, makes its appearance for the first time in connection with the art of electric lighting in the patent in suit.
>
> Complainant's counsel objects to the argument by defendant's counsel as having the same object as the question.

A. Yes.

326 x-Q. Then the fact that an Edison burner is bent into the hair-pin or horseshoe form, or that it is made of a material which permits of the burner being brought into the hair-pin or horseshoe form, has nothing to do with your classifying it among the "thread-like" or "filamentary" burners, has it?

A. No.

327 x-Q. In like manner, I suppose, the fact that the burners of the old carbon lamps, or at least the most of them, were straight and not looped, has nothing to do with your classifying those burners as "rods?"

A. No.

328 x-Q. If, for the sake of the argument, it be assumed that the term "filament" in the art of electric lighting means a burner specially adapted, by reason

of its size or its resistance, either or both, for use in *multiple arc* distribution, do you think there would have been any invention in substituting such a burner for one which, by reason of its size or its resistance, either or both, was adapted for use in *series* only—assuming, for the purposes of the question, that such a burner as the one last named had been previously used, and in a lamp structure substantially the same in construction as that in which it is assumed that the substituted burner is used?

Objected to as wholly unwarranted by the direct examination, also as incompetent.

A. The question does not state with definiteness all those conditions which I deem requisite to assist me in forming an opinion as to whether invention would be required in substituting the one burner for the other. Assuming a lamp chamber, like that used in modern lamps, containing a durable burner so large and of such low resistance as to be adapted for use only in series, then I should say that, at the date of the patent in suit, invention would not have been required to substitute for this burner a small burner of high resistance adapted for use in multiple-arc distribution—provided the method by which the large burner was made were adapted to the construction of the small burner.

Adjourned until September 17, 1890, at 11 A. M.

SEPTEMBER 17, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

Answer to 328 x-Q. continued.

Owing to the vague and general character of the question, I feel that my answer, which agrees with the

position which I have elsewhere taken upon substantially the same point, may be open to misinterpretation, and that further explanation is needed.

The assumption in the question as to the substitution of small burners adapted to multiple-arc distribution in place of large series burners is contrary to the order in which the actual substitution occurred. As a matter of fact, the first successful lamps had small burners, and were used in multiple arc; and series lamps with large burners were a later outgrowth of the development of the business. As I have before stated, I do not believe that the large series lamps mentioned in the question could have been first constructed and made durable, for it is only by increased skill obtained since the date of the patent in suit that that has become possible.

My position that, under the conditions which I have assumed, there would be no invention in substituting the small burners adapted for use in multiple-arc for the large burners adapted for use in series, is not based upon the assumption that the art had been for a long time and generally well acquainted with the measures which it was necessary to take in order to do this; but it is based upon the fact, as I understand it, that the art possessed this knowledge contemporaneously with Mr. Edison's work upon the electric light, and first obtained it in 1879, through the publication of his French patent for a platinum lamp, and, later on, from other foreign patents for the same invention.

329 x-Q. Was not the relation of a small burner to multiple-arc distribution pointed out in one of the Lane-Fox British patents, viz., No. 3988 of 1878—before the publication of the French patent of Mr. Edison to which you have just referred?

A. It may be that Lane-Fox intended to do so; but his language appears to me generally indefinite, as compared with the manner and completeness with which this relation is set forth by Mr. Edison in his platinum patent. And I very much doubt whether, with the views generally held by the art, concerning the impossibility of subdivision of the electric light, and the way in which its accomplishment was to be obtained if at all the Lane-Fox patent would have led the art to substitute the small carbon burners adapted for use in multiple arc in place of the large carbon burners adapted for use in series which have been referred to in my last answer.

330 x-Q. Please answer explicitly whether Lane-Fox, in the patent named, points out the necessity of small size and high resistance in the burners of incandescent lamps, when the lamps are to be arranged in multiple arc. I call your attention particularly to the sentence.

> "In order that the electric force may be conveyed at a high tension, that is, having high electro-motive force, so that there may not be very great loss from the resistance of the conducting mains or conductors, I make the lamps, when I use an alloy of platinum and iridium, of lengths of fine wires so that I may get a high resistance without having a large extent of luminous surface."

A. As I look at it, he points out the necessity of small size and high resistance, when the lamps are arranged in multiple arc, "*so that there may not be very great loss from the resistance of the conducting mains or conductors.*"

Adjourned for lunch.

Resumed.

331 x-Q. Does not Lane-Fox also lay special emphasis upon the arrangement of his lamps in *multiple arc*, having one or more claims in his patent which relate especially to this arrangement?

A. Yes.

332 x-Q. In answer to 328 x-Q you have said that at the date of the patent in suit there would have been no invention in substituting a carbon burner so small and

of such high resistance as to adapt it for use in multiple arc, for a burner so large and of such low resistance as to be adapted for use in series only, provided the lamp-chamber of the assumed prior lamp were like that used in modern lamps, and "*provided the method by which the large burner was made were adapted to the construc- of the small burner?*"

If now the method of making the large burner had *not* been adapted to the construction of the small burner, would it in your opinion have involved invention to devise a method of making a burner small enough for practical use in multiple arc.

A. Understanding, of course, that practically durable lamps are assumed in both cases, I will say that the devising of a method of making the small burners might involve invention; but I do not know whether this assumed invention would relate to carbon burners of all sizes which could be made by this method, or only to carbon burners small enough to be suitable for use in multiple arc, simply because they are small and can be so used. I think this is a question properly for the Court.

333 x-Q. You have repeatedly spoken of lamps having burners "adapted for use in multiple arc only," and also of lamps having burners "adapted for use in series only." How, with a given lamp, is one to determine whether it belongs to the one class or the other; and can you state the limits either as to size or resistance of a burner adapted for use in multiple arc only, or, on the other hand, of one adapted for use in series only; or, to put it in another way, do not these two classes of lamps shade into each other by insensible degrees, without any distinct line of demarcation between them?

A. The only criteria which I have in mind are the commercial lamps now in use. As to the size (diameter or cross-section) of the burners, some of those which are used in series lamps are larger, and others smaller, than some of those used in multiple-arc lamps. But in all cases the size of the burners of the 16-candle-power lamps is much smaller than that of any of the series lamps. As to resistance, that of all of the multiple-arc lamps made by the Edison Company is considerably greater than that of any of their series lamps. Of the lamps made by the Thomson-Houston Electric Company, a few of the series lamps have a resistance slightly greater than that of the multiple-arc lamps of high candle-power, but very much less than that of the multiple-arc lamps of low candle-power. Having regard to size and resistance, therefore, it may be said that the lamps of one class merge into the other. But considered in respect to those lamps of which the greatest number is in commercial use, the sizes and the resistances of the two classes of lamps are widely apart.

Adjourned until September 18, 1890, at 11 A. M.

SEPTEMBER 18, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

334 x-Q. You have repeatedly spoken (as in your answers to 308 x-Q. and 310 x-Q.) of the "lamps which have been most commonly used in multiple arc." What lamps have you intended to include in that designation?

A. In using the expression in the two answers referred to, I had particularly in mind the burners of multiple arc lamps not larger than the largest burner used in lamps made by the Edison Company and intended for use on circuits of high electro-motive force, the illuminating power of the largest of which, so far as I know, does not exceed one hundred candles.

335 x-Q. Have you used the expression quoted in

the last question in this same sense throughout your deposition?

Objected to as indefinite, unless the attention of the witness is called to the several instances which the counsel has in mind.

A. I can not say whether I have or not, because I cannot recall the particular instances where I have used this expression, if at all, and the language of the context which might explain its meaning.

336 x-Q. The Edison Municipal lamps are what you call "adapted for use in series only," are they not?

A. Yes.

337 x-Q. You, however, regard the burners of those lamps as "thread-like" or "filamentary," do you not?

A. Yes.

338 x-Q. Are those burners of substantially the same size as the burners of the Edison one hundred candle power lamp?

A. Understanding that the word "size" is used in the sense in which we have used it all along, that is, referring to the diameter or cross section, these burners are very nearly of the same size; but the burner of a one hundred candle power lamp has a considerably greater length and resistance than the burner of a Municipal lamp.

339 x-Q. What is the extreme difference in length between these two classes of burners?

A. The one hundred candle power burner is very nearly eight times as long as the fifteen candle power Municipal burner.

340 x-Q. When you have spoken of "size" as determining whether a burner be "filamentary" or a "rod," you had reference, did you not, to the area of the cross-section of the burner, rather than to its length?

A. Yes.

341 x-Q. If the length of one of the Municipal burners were reduced to one-quarter of an inch, the cross-

section remaining unchanged, would you call the burner "filamentary" or "thread-like"?

Objected to as immaterial.

A. I do not know. As I have before stated, I used the term "thread-like" or "filamentary" in the sense in which these terms are generally used, and in stating what sizes of burners I thought were in this sense "filamentary," I did not have the length of hypothetical burners in mind, but only that of those in actual use. From my understanding of the ordinary use of the terms, I thought that some were "thread-like" or "filamentary"; and in giving this opinion, took into account only the size or cross-section of the burners and not their length. Now, if a thread-like burner be indefinitily shortened, I do not know whether this term, in the ordinary sense, will still be applicable.

Adjourned for lunch.

Resumed.

Also present for complainant—G. P. Lowrey, Esq.

342 x-Q. If a carbon of a given cross-section and nine inches in length is "filamentary," in your understanding of the term, and if a carbon of substantially the same cross-section but only about an inch in length also be "filamentary," but you are in doubt as to whether a carbon of the same cross-section, whose length is only one-fourth of an inch is "filamentary," you will admit, I suppose, that the meaning of this term depends to some extent upon the *length* of the object to which it is applied.

Question objected to as being argumentative only, and as not calling for an answer, since it merely states what Gen. Duncan supposes.

Question withdrawn.

343 x-Q. In view of the fact that you regard the burner of the Edison 100 candle-power lamp, which is nine inches in length, as "filamentary," and also regard the burner of the 15 candle-power Municipal lamp as "filamentary," this latter burner being of substantially the same cross-section as the former, but only a little more than one inch in length, do you not think that the meaning of the term "filamentary" is dependent to some extent upon the *length* of the burner to which it is applied?

A. I do not see that that follows from the statement in the question, for while I consider one of the burners to be filamentary, the other burner of nine times the length is in my opinion also filamentary. Standing by itself, I think that this would indicate that in my opinion the question as to whether a burner is filamentary or not is independent of its length. As a matter of fact, I think it does to some extent depend upon the length, but that the diameter or cross-section is in the main the controlling factor.

344 x-Q. You have said that you do not know whether a burner of the size of one of the Edison Municipal burners and one-fourth of an inch in length is "filamentary?" Would a burner one-fourth of an inch in length and of a cross-section only one-fourth or one-tenth that of the Municipal burner be "filamentary"?

Objected to as immaterial and irrelevant.

A. I think so.

345 x-Q. What is there about such a burner that makes it filamentary which does not also exist in connection with a burner of the same length and having a cross-section equal to that of the Municipal burner?

A. A smaller cross-section which in my opinion makes the term applicable to it.

346 x-Q. Then you think, do you not, that the cross-section of a carbon of the *size* of a Municipal burner, provided its length be but a quarter of an inch, is so great as to make it doubtful whether such a burner can properly be called filamentary?

A. No. I should say that its length is such as to make it doubtful whether it can be properly called filamentary or not.

347 x-Q. I have supposed a case of two burners having precisely the same length and differing in no other respect than as to the areas of their cross sections. One of these you have declared to be "filamentary;" as to the other you have said in substance that you do not know whether it can properly be called filamentary or not. Now, why is it not the *size* of this last burner and not its *length* that makes you uncertain as to whether or not it be filamentary?

A. Because if its size remains unaltered and its length were four times as great—the length of the Municipal burner—I should call it filamentary. I think it proper to ascribe a result to that which produces it.

348 x-Q. You would also call it filamentary if its length were not increased, provided its cross-section were diminished to that of the smaller one of the two burners that we are talking about. Therefore I press my question whether it is not in fact the *size* of the larger of these two burners and not its *length* which makes you doubt as to the propriety of calling it filamentary?

A. Considering these burners by themselves and not as having any particular relation to the size or length of any other burners, I answer, yes.

349 x-Q. Now will you please explain how it is that the *size* (that is, area of cross-section) of a carbon whose length is one-fourth of an inch may be so large as to make it doubtful whether or not the carbon be filamentary, while that same *size*, if the length be increased, will be so small as to make the carbon unquestionably filamentary?

A. Because I think that the definition of the term and the general sense in which it is used make it applicable to the last mentioned burner, in that it is small and slender.

Adjourned till September 19th, at 11 A. M.

SEPTEMBER 19, 1890.

Met pursuant to adjournment.

Present—GROSVENOR P. LOWREY, of counsel for complainant, and SAMUEL A. DUNCAN, of counsel for defendant.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

350 x-Q. Please state where you find any warrant for saying that a piece of carbon whose cross-section is 0.0002744 of an inch (being the cross-section of the Edison Municipal burner), and whose length is one-fourth of an inch, is not "small and slender," while a carbon of the same length and of one-fourth this cross-section *is* "small and slender."

A. I base my opinion upon the dictionary definitions of the terms "filamentary" and "thread-like," and analogous terms, and the sense in which I understand they are ordinarily used. I have not said that the first-mentioned carbon is not small and slender enough to be called filamentary in the ordinary sense. I simply do not know whether it is or not; whereas I think that the term is properly applicable to the burner last-mentioned in the question.

351 x-Q. What do you find in the "dictionary definition" of the word "small," or the word "filamentary," or the word "thread-like," that leads you to doubt whether the larger of the two burners spoken of in the last question is properly included under the said terms?

A. A "filamentary" body is one having the character of a filament, and a "filament" is a thread or thread-like object. A "thread" is a *small* line or twist of any fibrous substance, and both "thread-like" and "thready" bodies are defined as resembling threads—and the latter is also defined as being *slender*. The word "small" is defined as "not large or extended in dimension; little in quantity or degree; minute in bulk; diminutive." And the word "slender" is defined as "small in circumference compared with the length or height; slim; thin." From the definitions of the words "small," "filamentary" and "thread-like," taken in connection with their use in the defining of the words "filament," "thread," "thready" and "slender," and from the use of several of these terms in defining the others, as well as my understanding of the sense in which they are ordinarily employed, I do not know whether the terms mentioned in the question are properly applicable to the larger of the burners referred to.

352 x-Q. Taking the definition of the word "small" as given in your last answer, will you say that you do not know whether the larger burner referred to in 350 x-Q. falls within the definition?

A. I think that the burner can properly be called "small." I notice that there is an apparent contradiction between this and my last answer, in which I I have said that I did not know whether the burner was small or not. In giving that answer I had before me for consideration not only the word "small," but also the words "filamentary" and "thread-like;" and in expressing my opinion I had in mind the term "small and slender," made use of in several previous answers, and intended to say that I did not know whether the burner was "thread-like," or "filmamentary, or "*small and slender*" enough, to come within these definitions.

Adjourned for lunch.

Resumed.

353 x-Q. Will you say that you do not know whether the larger of the burners referred to in 350 x-Q. is *slender*—the length of such burner, if I am right in the matter, being more than twelve times its diameter?

A. As defining thready or thread-like burners, I do not know whether the term is appropriate or not.

354 x-Q. Your answer seems to me evasive. I wish to know whether you have any opinion upon the point inquired about in my last question. Is the burner therein referred to in your judgment slender, or are

you unable to form an opinion upon the subject? It seems to me that I am entitled to a direct answer upon this question.

Objected to as irrelevant and immaterial.

A. In the sense in which I have used this term, as applied to thread-burners, I do not know whether the burner referred to is slender or not.

355 x-Q. Doesn't such a burner come plainly within the definition of the term "slender," which you have recently quoted from the dictionary in support of a former answer?

> Objected to, because it is the province of the Court and not of an expert electrician to apply the dictionary definitions to an object whose dimensions have been given.

A. I do not know.

356 x-Q. If, in applying the definition of "slender," which you have quoted from the dictionary, you cannot form an opinion as to whether a piece of carbon twelve times as long as its diameter, is slender, how are you able to say that that same carbon would be slender if its length were quadrupled, in the absence from such definition of any exact proportion?

A. I can only say that such is my opinion, based upon what I understand to be the definition of the term, and the sense in which it is commonly used, and my understanding of its proper application to the burners of incandescent lamps.

357 x-Q. "Commonly used" by whom?

A. I think that any one would call a body slender if the length were fifty times its diameter, which is about the relation of the length and diameter of the burner referred to.

358 x-Q. Then in your last answer, when you used the words "*is* commonly used," you meant, did you not, the sense in which *you think* that the term *should be* commonly used?

A. Not exactly. I think that it not only should but would be commonly so used.

359 x-Q. I understood you in the last answer but one to assert, impliedly, that it *is* in fact commonly so used. Did you mean to so state?

A. Yes.

360 x-Q. The use of the Edison 100 candle-power lamps and the Edison Municipal lamps, is very limited, is it not, as compared with the use of the Edison 10 and 16 candle-power lamps?

A. I cannot say as to the 10 candle-power lamps; but as to the 16 candle-power lamps, they are used in much greater numbers than the 100 candle-power and Municipal lamp.

361 x-Q. Would you classify the burners of these Edison 100-candle-power and Municipal lamps among the *larger* or the *smaller* burners of modern incandescent lamps?

A. I should class them among the smaller as to diameter or cross-section.

362 x-Q. In answer to 273 x-Q., you give it as your opinion that the "invention described in the patent in "suit solved the problem of subdivision, because it in-"structed the art how to make lamps adapted for use in "multiple arc," etc. If the patent had described only a lamp adapted for use *in series*, do you think that this also would have been a solution of the problem—assuming, if you choose, that such lamp were made by a process that would have been applicable equally to the making of multiple-arc lamps?

A. Bearing in mind the statement above quoted from my answer to 273 x-Q. related to lamps made by the process described in the patent in suit, and calling attention to the fact that the patent, contrary to the limitation imposed by the question, describes a lamp adapted for use in multiple arc, and also that modern lamps were first made and adapted for use in this manner and not in series—as is more fully set forth in my answer to 328 x-Q.—I answer, yes.

Adjourned until September 20, 1890, at 11 A.M.

September 20, 1890.

Met pursuant to adjournment.

Present—R. N. Dyer, of counsel for complainant; S. A. Duncan, of counsel for defendant.

Cross-examination of the Witness, Charles L. Clarke, continued:

363 x-Q. What do you mean by the expression in your last answer, "lamps made by the process described in the patent in suit"—the same expression having, I think, been frequently used by you before?

A. I mean the process of making lamps of high resistance and small radiating surface, which consists in reducing the burner—made of carbonizable material—to size and shape prior to its carbonization, and its subsequent enclosure in a chamber made of one continuous piece of glass, into the walls of which the conducting wires are sealed by fusion of the glass around them; and, lastly, the exhaustion of the air until a very high vacuum is obtained, and the permanent sealing up of the opening by fusion of the glass.

364 x Q. Do you by this answer mean to indicate that the process of the patent requires lamps to be of "high resistance," and if so, do you mean by this high *specific* resistance or high *total* resistance?

> Objected to as incompetent, as unwarranted by the direct examination, and as calling for a legal construction of the patent.

A. I do not know what the patent may require. I simply find in it a description of a process of making a lamp consisting in certain operations upon certain materials.

365 x-Q. In answering 363 x-Q., then, you assumed, did you not, that the lamp described in the patent was a lamp of high resistance?

A. No. I did not make any assumption as to the character of the lamp as technically construed by the patent, to which I understand the question refers. I simply had in mind the fact that a lamp of high resistance is described in the specification.

366 x-Q. You have repeatedly used the expression, "lamps made by the process described in the patent in suit." In 363 x-Q. I asked you what you meant by that. You answered that you meant "the process of making lamps of *high resistance*," etc. Did you by that expression mean lamps of high *specific* resistance or lamps of high *total* resistance; or, was the use of the term "high resistance" in 363 A. an inadvertence on your part?

A. I intentionally made use of this expression, having in mind that the specification describes a lamp of high resistance, and likewise describes a process of making lamps which is applicable to the manufacture of lamps of high resistance.

366 x-Q. I still press the question whether by that expression you intended high *specific* resistance or high *total* resistance?

A. I had in mind high specific and high total resistance and small radiating surface, without, however, intending in any way to limit the application of this process so as to exclude the accomplishment of any other result which might be obtained by its use. As there seems to be some confusion as to the meaning of my answer to 363 x-Q., I will state that I intended to say that the process described in the patent in suit consists in certain operations upon certain materials (given in that answer in detail), and that the making of a lamp of high specific and high total resistance and small radiating surface with the aid of this process is described in the specification.

Adjourned until Monday, September 22, 1890, at 11 A. M.

September 22, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

367 x-Q. Then you do not hold, do you, that "the process of the patent in suit" is "a process of making lamps of high resistance and small radiating surface," but, rather, a process of making lamps *generally*, which, while applicable to lamps of high resistance and small radiating surface, is also applicable to lamps of low resistance and comparatively large radiating surface?

Objected to as incompetent if intended to call for a legal construction of the patent.

A. The statement in the question does not in all respects correctly represent the position which I take. While the process of making the lamps described in the specification is a process which is applicable to the making of lamps of low total resistance and of comparatively large radiating surface, as well as others of high total resistance and small radiating surface, I believe that it is the only process by which lamps having the characteristics last mentioned can be made. As to the quality of the carbon of the burners, I think that the result of this process causes it to be of high specific resistance.

368 x-Q. Do you mean to say, then, that the statement of my last question misrepresents your position?

A. If in the question referred to the expressions "high resistance" and "low resistance" pertain only to the *total* resistance of the burners, then so far as it goes, the statement in said question agrees with the position which I take. But in addition to this, I also hold that a result of this process of great advantage is the production of burners, the carbon of which has a high *specific* resistance, from which it results that the ratio of the total resistance of the burner to the extent of its surface is greater than if the carbon were of low specific resistance.

Answer objected to as not responsive.

369 x-Q. 367 x-Q. did not undertake to enumerate the *results* of "the process of the patent in suit." I still ask you whether it misrepresents you as to the matter inquired about?

A. With the understanding that the lamps referred in 367 x-Q. embody in them the results which I have mentioned of applying this process, then the statement in said question represents my position.

370 x-Q. Do you intend this as an affirmative or a negative answer to my last question?

A. Bearing in mind that the process is, as I understand it, only applicable to making burners, the carbon of which will have a high specific resistance, my answer is a negative one.

Adjourned for lunch.

Resumed.

371 x-Q. In your last answer, as well as in your answer to 367 x-Q., you take the position that "the process of the patent in suit" necessarily results in the production of a burner the carbon of which will have a "*high specific* resistance." What do you mean by a carbon of *high specific* resistance?

A. Practically I mean carbon, a cubic centimeter of which has a high resistance as compared with the resistance of a cube of dense gas or unplated arc-light carbon of the same size.

372 x-Q. By the words "high resistance as compared with," do you mean *higher resistance than?* If not this, what do you mean?

A. I did not have in mind any exact line of demarcation, but my answer had more particular reference to the specific resistance of the carbon of the burners of modern incandescent lamps as compared with the resistance of the gas and unplated arc-light carbon before mentioned. Personally I have not made any calculations of this character, but a careful consideration of the second deposition of Professor Barker in this suit, wherein this question of specific resistance is dealt with, leads me to fully agree with him in the position which he takes in the concluding paragraph of his answer to 4 Q., in which he states in substance that the carbons of defendant's lamps have a high specific resistance as compared with dense and unplated arc-light carbons.

Answer objected to as not responsive.

373 x-Q. Question repeated.

A. I did not use it in the sense that any specific resistance higher than this—no matter how small the difference—would be properly termed a high specific resistance, but had in mind a considerably higher specific resistance; so high, in fact, that a comparison between the two would perhaps be more properly expressed by ratio than by absolute difference.

Adjourned until September 23, 1890, at 11 A. M.

September 23, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

Cross-examination of the Witness, Charles L. Clarke, continued:

374 x-Q. What *ratio*, then, would you fix as a measure of that specific resistance which, in comparing the resistance of the carbons produced by the process of the patent in suit with that of the old carbons, you have characterized as "high"?

A. I am unable to *fix* any particular ratio which may serve as a standard of comparison to determine for all cases whether the specific resistance of different carbons is high or low. But I should consider that the ratio of the specific resistance of the dense and unplated arc-light carbons—which, as I understand it, would have a specific resistance of from 600 to 1,000 microhms—as compared with that of the carbons of modern incandescent lamps, would make it proper to class the latter as being of high specific resistance. The lowest specific resistance of the burners of modern incandescent lamps of which I have knowledge is 3,800 microhms, which would mean a ratio of from 1 to 3.8 in one case and 1 to 6.3 in the other.

375 x-Q. In other words, a carbon, in order to have a "*high* specific resistance," as you have used this expression in connection with the carbons produced by "the process of the patent in suit," must have a specific resistance from, say, 3½ to 6 times that of the old arc-light carbons?

A. No, I did not have the patent in mind. I simply considered that the one carbon as compared with the others could properly be considered as of high specific resistance.

376 x-Q. You should have had in mind the process of the patent, since that is the very matter which has for some time past been under discussion. In answer to 370 x-Q. you took the position that *the process of the patent* is "only applicable to making burners, the carbon of which will have a high specific resistance." The next three questions sought to ascertain from you what you meant by the term "*high* specific resistance" when speaking of the results of "the process of the patent in suit;" and you said in substance (in answering 373 x-Q.) that it must be a resistance so much higher than that of dense and unplated arc-light carbons that the relation between the two would more properly be expressed by a ratio than by absolute figures. And in 374 Ans. you undertake to state the ratio between the arc-light carbons and the *lowest* specific resistance of the carbon of the burners of modern incandscent lamps, all of which you have said elsewhere are produced by the process of the patent in suit.

Now, please explain why you did not have the process of the patent in suit in mind in answering the question before the last, and why the ratio stated in the last question is not to be accepted as your statement of the ratio between the resistance of the arc-light carbons referred to and that of a carbon made by the process of the patent in suit?

A. It is true that in answer to 370 x-Q. I have said that the specific resistance of carbons made by the process described in the patent will in my opinion be "high," but I did not by that intend to say that carbon having a lower resistance than could be obtained by this process alone would not also be of high specific resistance. In saying that modern lamps are made by the process described in the patent, I did not intend to exclude the fact that in some lamps (one of which I have referred to in the comparison made in my answer to 374 x-Q.) the carbon is subjected to a subsequent process which lowers the specific resistance. Neither did I intend to say that such carbons would not be of high specific resistance. For these reasons I did not have the process described in the patent in mind in answering the question referred to, and do not think that the ratio beforementioned is to be excepted as my statement of the ratio between the resistance of the arc-light carbons and that of carbon made by the process described in the patent, but rather that it is the statement of the ratio as between the arc-light carbons and that carbon used in modern incandescent lamps having the lowest specific resistance of which I have knowledge.

Adjourned for lunch.

Resumed.

377 x-Q. Inasmuch as, under your present explanation of the statements which you made in the form of an answer to x-Q. 374, said answer manifestly would not be responsive to the question, I will repeat the said question, and ask you to answer *it*, and not turn

aside to the attempted discussion of a different subject?

A. The only data which I have at hand concerning the specific resistance of the carbon of the lamps made by the process described in the patent which have not been subjected to any other subsequent process are derived from the dimensions of the Edison lamps, a list of which forms an exhibit in this suit. I find that the specific resistance of the carbon of the 16-candle-power new lamp is 4,900 microhms, and that of the 16-candle-power old lamp is 4,600 microhms.

Understanding that the specific resistance of the dense carbons of old lamps would be from 600 to 1,000 microhms, as I have already stated, in my opinion—the ratio of the specific resistance of the Edison carbon last above mentioned being, as compared with that of the dense carbons, as 7.7 to 1 in one case and 4.6 in the other case—the Edison carbon can be truly said to be "of high specific resistance." I do not, however, wish to be understood as saying that this expression would not be applicable to a carbon of lower specific resistance than that of the one referred to.

378 x-Q. If it be applicable to carbons of lower specific resistance than this, what is the *lowest* specific resistance which carbons produced by the process of the patent in suit can have, and yet have their resistance "high," in the sense in which you have used this term when you have set forth that the process of the patent necessarily produces a carbon of "*high* specific resistance?

A. I do not know the *lowest* specific resistance which carbons produced by this process could have, without the application of some subsequent process, but do not think that it would be possible to make carbons by this process, without additional treatment, which would have a specific resistance less than 3,800 microhms—the same being the specific resistance of the lamp mentioned in my answer to 374 x-Q.

Adjourned until September 24, 1890, at 11 A. M.

SEPTEMBER 24, 1890.

Met pursuant to adjournment.

Present—Counsel as before and G. P. LOWREY, ESQ., of counsel for complainant.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

379 x-Q. You have assumed in your last few answers, have you not, that the Edison burners, whose specific resistance you have stated, have been made without being subjected to what you call "any other subsequent process"—meaning thereby, as I understand, any process subsequent to "the process described in the patent?"

A. Yes.

380 x-Q. Are not all of the Edison burners treated electrically subsequent to their carbonization, and while the lamp bulb is being exhausted?

A. Yes. They are subjected to this treatment.

381 x-Q. And does not that subsequent treatment materially reduce the specific resistance which the carbon has on leaving the carbonizing furnace?

A. Yes.

382 x-Q. About how much?

A. That I cannot state with exactness. I notice that Mr. Howell states, in answer to 79 x-Q. and 80 x-Q. of his deposition given in this case, that the reduction in specific resistance of the burners of the Edison lamps is about 20%, and that this fairly represented the reduction by this treatment, as carried on by the Edison Company in November, 1888. From what I know of the subject generally, I see no reason to doubt the substantial correctness of Mr. Howell's statement.

383 x-Q. Then, in stating the specific resistance of the Edison burners, as resulting from the process of the patent in suit, ought you not to have given their resistance as it stood prior to the electrical treatment of the pumps, thus making it in the neighborhood of 20% higher than you actually stated?

A. No, I see no reason for so doing, understanding as I do that the process described in the patent instructs the art to apply this electrical treatment to the carbon burner.

384 x-Q. What language in the patent "instructs the art" to treat the carbons electrically during the process of exhausting the globe?

A. The specification states that:

> "The invention further consists in placing such burner of great resistance in a nearly perfect vacuum, to prevent oxidation and injury to the conductor by the atmosphere."

And, in regard to lamps made prior to the date of the patent,

> " * * * that owing to the low resistance of the lamp the leading wires must be of large dimensions and good conductors, and a glass globe cannot be kept tight at the place where the wires pass in and are cemented; hence the carbon is consumed, because there must be almost a perfect vacuum to make the carbon stable, especially when such carbon is small in mass and high in electrical resistance."

It is also stated that:

> "The use of a gas in the receiver at atmospheric pressures, although not attacking the carbon, serves to destroy it in time by 'air washing' or the attrition produced by the rapid passage of the air over the slightly coherent highly heated surface of the carbon."

The inventor, after stating that he has "reversed this practice," goes on to say:

> "I have discovered that even a cotton thread, properly carbonized and placed in a sealed glass bulb exhausted to one-millionth of an atmosphere, offers from one hundred to five hundred ohms resistance to the passage of the current, and that it is absolutely stable at very high temperatures."

In the light of the above quotations it seems to me that the specification fully sets forth the necessity of having a very high vacuum in the lamp.

Adjourned for lunch.

Resumed.

Answer continued.

To obtain such a vacuum I believe that the art would recognize the necessity of removing the gas contained in the pores of the carbon burner by heating it to incandescence and pumping out the occluded gas, in view of the instructions contained in U. S. Letters Patent No. 210,809 and No. 211,262, granted to Sawyer & Man, and in Edison's French Patent No. 130,910 of May 28, 1879, and his English Patent No. 2,402 of December 17, 1879—and would, without any further instructions, electrically heat the burners in the process of exhaustion and obtain a high vacuum.

In regard to this electrical heating and my statement that the burners in the Edison lamps have not been subjected to any process, subsequent to the process described in the patent, I wish to say that in using the expression "subsequent process" I had particularly in mind the so-called "hydro-carbon process," by which carbon is electrically deposited within the pores and upon the surface of the burner, and its specific resistance is reduced.

385 x-Q. Do you then mean to say that the patent in suit describes this electrical treatment on the pumps, so that this treatment becomes a part of "the process described in the patent?"

A. Yes, because I believe that the positive manner in which the necessity of a high vacuum is stated in the patent amounts to an instruction to the art to electrically heat the burners on the pumps; that being, as I understand it, the well-known and only way by which a high vacuum could be obtained, and which, I think, would be at once adopted.

386 x-Q. Evidently, then, you regard this electrical

treatment on the pumps as a part of the operation of producing the high vacuum, and not as a part of the process of carbonization. How is this?

A. I should say that in the main it is to be considered as a part of the operation of producting a high vacuum. One result of this treatment is, I believe, to bring the burners to a higher state of carbonization, the resulting effect depending somewhat upon the length of time during which they are kept in the carbonizing furnace and the temperature to which they have been subjected.

387 x-Q. Regarded as a part of the process of carbonization, do you find any description of this process of electrical treatment in the patent in suit?

Objected to as indefinite.

A. What process of carbonization, may I ask?

388 x-Q. The process of carbonization referred to in the patent, of course.

A. Yes. The specification states that:

> "I have discovered that even a cotton thread properly carbonized and placed in a sealed glass bulb exhausted to one-millionth of an atmosphere offers from one hundred to five hundred ohms resistance to the passage of the current, and that it is absolutely stable at very high temperatures."

Under the conditions above quoted the carbon would be subject to this extra carbonization.

Counsel for complainant states that in introducing from the McKeesport case into this case the depositions of Thomas A. Edison, Charles Batchelor, Francis R. Upton, Hugh R. Garden, George W. Sawyer, William Sharp and Walter K. Griffen, various offers of exhibits on behalf of the complainant were also introduced, some of which exhibits have been lost or are not accessible and cannot be filed in this case. Counsel for complainant give notice that the

exhibits referred to as lost or inaccessible are as follows:

Edison's Exhibit First Incandescent Lamp offered before Q. 28 of the deposition of Thomas A. Edison.

Edison's Commerical Incandescent Electric Lamp offered before Q. 34 of the same deposition.

Edison's Exhibit No. 15 offered before Q. 29 of the deposition of Charles Batchelor.

Edison's Exhibit No. 16 offered before Q. 43 of the same deposition.

Edison's Exhibit No. 17 offered at the same point.

Edison's Exhibit No. 18 offered at the same point.

Edison's Exhibit No. 19 offered at the same point.

Edison's Exhibit No. 20 offered at the same point.

Edison's Exhibit No. 21 offered before Q. 44 of the same deposition.

Edison's Exhibit No. 22 offered at the same point.

Counsel for complainant gives notice that the following exhibits (the offers of which were also introduced with the testimony from the McKeesport case) being offered in evidence at other points in the record, either by the complainant or by the defendant, he desires to withdraw the offers made at the following points in the record:

Edison's Exhibit No. 8 offered before Q. 61 of the deposition of Thomas A. Edison.

The several letters patent offered before Q. 371 of the same deposition.

Defendant's Exhibit Edison's Patent No. 223,-898, offered before Q. 412 of the same deposition.

Defendant's Exhibit Edison's Patent No. 227,-229 offered at the same point.

Defendant's Exhibit Bamboo Patent No. 251,-540, offered before Q. 437 of the same deposition.

Adjourned until September 25, 1890, at 11 A. M.

September 25, 1890.

Met pursuant to adjournment.

Present—R. N. Dyer, of counsel for complainant, and S. A. Duncan, of counsel for defendant.

Cross-examination of the Witness, Charles L. Clarke, continued:

389 x-Q. I understand you to say in substance that the patent in suit describes the electrical heating of the carbon burner while the lamp globe is being exhausted, and describes this as a necessary part of the process spoken of in the patent as "carbonization." Do you really hold any such view as that?

A. No.

390 x-Q. What, then, do you understand that the patent means by the terms "carbonized" and "carbonization" and "carbonizing?"

A. I think that where these terms are used in the patent they refer to that part of the carbonizing process which takes place in the furnace.

391 x-Q. Then, of course, you agree that the patent makes no direct reference to the process of electrical heating on the pumps?

A. If by the expression "no direct reference" it is asked whether the patent refers to the "process of electrical heating" in so many words, then I answer yes, at the same time, however, calling attention to my answer to 385 x-Q., to the effect that this process is described in the patent in other language.

392 x-Q. At the date of the patent in suit had it become known to the art that it was absolutely necessary to the production of a practical and durable incandescent lamp that the carbon burners should be subjected to electrical heating during the process of exhausting the globe?

A. I do not think that the question, if answered in the affirmative, would represent the condition of the knowledge which the art had prior to the date of the patent. In my opinion, it was known that by electrically heating the carbon burner in the presence of an inert gas during exhaustion the air in the pores of the carbon would be expelled and removed from the lamp chamber, and that the durability of the carbon burner would for this reason be increased. As I understand it, a high degree of exhaustion was not contemplated or deemed necessary; but, on the contrary, the lamp chamber remained filled with inert gas at the end of the operation.

Adjourned for lunch.

Resumed.

393 x-Q. In this you refer doubtless to the Sawyer and Man Patents Nos. 210,809 and 211,262, as most fully representing the state of the art upon the subject now under discussion as it existed prior to the date of the patent in suit?

A. Yes, as representing the state of the art with reference to the presence of air in the pores of a carbon burner, and a method of expelling the same in the presence of an inert gas by electrical heating.

394 x-Q. Where in the art prior to the date of the patent in suit do you find the best statements, or any statements, in regard to the use of the electrical heating of the carbon burner of an incandescent lamp during the process of exhausting the globe, either for the purpose of perfecting the carbonization of the material composing the burner or for aiding the pumps in perfecting the vacuum in which the burner was to be used.

A. I do not know of any statement contained in the literature of the art of incandescent lighting, prior to the date of the patent in suit, which will conform to the conditions set forth in the question. That could hardly be expected, for the reason that it was not known that there would be any advantage in placing the carbon burner in a high vacuum, and that the method of constructing the old carbon lamp chambers with separable parts and large leading-in wires cemented into their walls precluded the possibility of either obtaining or preserving such a vacuum.

I believe, however, that the directions given in the specification of the patent in suit would, in the light of statements contained in the Sawyer & Man and in the Edison patents referred to, instruct the art to electrically heat the carbon burner during the process of exhausting the globe for the purpose of aiding the pump in perfecting the vacuum, and resulting also in its additional carbonization.

Adjourned until September 26, 1890, at 11 A. M.

SEPTEMBER 26, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

395 x-Q. Do the Sawyer & Man patents anywhere indicate that the electrical heating of the carbon to which they in part refer was for the purpose of effecting what you call "additional carbonization," or that it produced this result?

A. I find no statement of this character.

396 x-Q. Do you find in the said Sawyer & Man patents any indication that the electrical heating of the carbon was for the purpose of securing a higher vacuum than could have been obtained without it, or that it in fact operated to produce such a result?

A. No.

397 x-Q. Is it not a fact also that this process of electrical heating of the carbon, as the same is described in the two Sawyer & Man patents, was to take place always in the presence of a nitrogen gas?

A. Yes.

398 x-Q. So far as concerns the condition of the material composing the burners to be subjected to the electrical heating contemplated by the two Sawyer & Man patents, is there anything in those patents which indicates that such material was not completely carbonized before the electrical heating began?

A. I do not think so.

399 x-Q. Is there anything in the Sawyer & Man patents to indicate that the electrical heating was to be applied to any other form of carbon burner than a "pencil?"

A. I see no indication in the patents that the use of any other form of burner was contemplated.

400 x-Q. Does this term "pencil" in these patents mean substantially what you have spoken of in this deposition as "rods"?

A. I think so.

Adjourned for lunch.

Resumed.

401 x-Q. You are also of the opinion, are you not, that the lamp described and referred to in the Sawyer & Man patents was of no practical value for commercial purposes?

A. Yes.

402 x-Q. Now, will you explain how it is that these Sawyer & Man patents, which deal only with *pencils* or *rods* of carbon, and which, in your opinion, describe a lamp of no practical value, justify the conclusion (which I understand you to entertain) that at the date of the Edison patent in suit (which you admit contains no statement in regard to the electrical treatment of the carbon burner) a person on reading said Edison patent would have known that it would be necessary to the production of

a practical lamp with a *filamentary* burner to subject such burner to a high electrical heating during the exhausting of the lamp globe, in order to secure a more perfect vacuum and one without which the burner would not be sufficiently stable for practical purposes, and in order to perfect the carbonization of such burner—especially in view of the further facts, admitted by you, that the Sawyer & Man patents contain nothing to indicate that the electrical heating of which *they* speak has any useful function to perform, by way either of producing a vacuum (a thing not contemplated by the Sawyer & Man patents) or by way of improving the carbonization of the burner (since, apparently, this was to be completely carbonized before the electrical heating began)?

Objected to as indefinite and argumentative; also as containing statements not warranted by the evidence.

A. I do not hold the opinion that at that date and after reading the patent in suit, the Sawyer & Man patents alone would justify the conclusion contained in the question.

403 x-Q. Where else, prior to the date of the patent in suit, if not in these Sawyer & Man patents, do you find any description of the use of electrical heating as applied to the carbon burner of an incandescent lamp during the process of exhausting the globe of such lamp, either for the purpose of perfecting the carbonization of the material composing such burner, or for the purpose of producing a vacuum sufficiently high to render the carbon practically stable?

A. Nowhere. As I understand it the patent in suit first instructed the art to make use of electrical heating of carbon burners to aid, in the obtaining of a high vacuum, resulting also in the perfecting of their carbonization, and in rendering them practically stable.

Adjourned until September 27, at 11 A. M.

September 27, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

Cross-examination of the Witness, Charles L. Clarke, continued:

404 x-Q. Where in the art, prior to the date of the patent in suit, do you find instruction in regard to the electrical heating of the carbon burner of an incandescent lamp, during the process of exhausting the globe, *for the purpose of perfecting the carbonization of the material composing the burner?*

Objected to as already answered.
Counsel for defendant asks where.
Counsel for complainant calls attention to answer to cross-question 403.

A. Nowhere.

405 x-Q. You regard this process of electrically heating the carbon burner of an incandescent lamp during the exhausting of the globe as absolutely essential to the construction of a practically useful lamp?

A. Yes; I have already stated that to be my opinion in answers to 205th to 211th cross-questions, inclusive.

406 x-Q. One thing in your testimony, if I understand aright your premises, is surprising. I wish, therefore, to ascertain whether I do correctly understand your position on the subject now under discussion.

I understand you to admit that, prior to the date of the patent in suit, it was not known to the art that electrical heating of the carbon burner of an incandescent lamp while on the pump was necessary, either by way of perfecting the carbonization of the burner or by way of improving the vacuum; but that the art got its instruction as to the value of this essential step in the process of making an incandescent lamp from the patent in suit, and from that part of the patent in suit which requires simply that the lamp globe be exhausted to a *high vacuum*.

Now, on the premises stated (if these be correct), how can it follow that on the 27th of January, 1880, a person would have found in this simple direction of the Edison patent instructions to supplement the action of the carbonizing furnace and the action of the air-pump by subjecting the carbon burner of the lamp to electrical heating during the process of exhausting the globe?

A. In my opinion this would very naturally follow, and for the following reasons.

As I understand it, prior to the date of the patent in suit, it was not known that any advantage would result from placing a carbon burner in a very high vacuum, or that by so doing a carbon burner could be made which would be durable enough for practical commercial purposes. Now, the patent in suit calls attention to the absolute necessity of exhausting the lamp globe to a very high degree, not by any *simple* reference to a *high vacuum*, as intimated in the question, but, as I believe, in a most emphatic manner, by stating that the burner is to be placed "in a *nearly perfect vacuum*, to prevent oxidation and injury to the conductor by the atmosphere;" that "there must be *almost a perfect vacuum* to render the carbon stable;" and that "a cotton thread properly carbonized and placed in a sealed glass bulb exhausted to *one-millionth of an atmosphere* offers from one hundred to five hundred ohms resistance to the passage of the current, and that it is absolutely stable at very high temperatures." The patent also states that the globes of the old lamps cannot be kept tight, and that for this reason the carbon is consumed. Reference is also made to the lamp chamber described in the patent, which is made of one continuous piece of glass, as a "*vacuum bulb;*" and that it is hermetically sealed when a "*high vacuum*" has been reached; also that platinum is the only material that can be used for leading-in wires, because its expansion is nearly the same as that of glass; and, again, that the current is conducted into the vacuum bulb through these wires, which are "*sealed*" into the glass, and that, because they are small in resistance as compared with the

burner, *fine* wires may be used which will not heat and crack the "*sealed vacuum bulb.*"

I think that these references in the patent to the absolute necessity of having a very high vacuum, so that the carbon will be stable, and the particular description of a sealed chamber made of one continuous piece of glass, with fine platinum leading-in wires sealed into its walls for the particular reason that they will not "crack the sealed vacuum bulb," would lead the art to at once understand the necessity of electrically heating the carbon burner during the process of exhausting the globe in order to secure such a vacuum, resulting also in the additional carbonization of the burner, because the Sawyer and Man patents teach that there is air in the carbon, which is expelled from it by electrical heating, but which acts injuriously if allowed to remain in the lamp chamber; and also because the French and English patents of Edison before mentioned teach that a burner made of platinum wire contains air in its pores, and that by expelling this air by electrical heating during the process of exhausting the globe a very high vacuum is obtained, and likewise refer to the fact that the air contained in sticks of carbon may be expelled in this manner.

I feel strengthened in my opinion by the confirmation which it receives from the opinion expressed by Professor Elihu Thomson, one of defendant's witnesses, who, as I understand it, in his answers to 143-148 x-Qs., inclusive of his deposition in this case, states that the Sawyer and Man patents describe a process of heating the carbon for the purpose of driving the air and gas out of the burner, and that Edison's French patent describes it, in connection with his platinum lamp, and also refers to it as being suitable for use with carbon, and furthermore expresses the opinion that, upon reading the patent in suit, proper skill and judgment would lead one to electrically heat the carbon during exhaustion in order to drive the air out of the carbon and to obtain a high vacuum.

Adjourned until Monday, September 29, 1890, at 11 A. M.

September 29, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

Cross-examination of the Witness, Charles L. Clarke, continued:

407 x-Q. It goes without the saying, I think, that the patent in suit contemplates a high vacuum as one of the conditions of a useful lamp; but where, either in the patent or in the art prior to the patent, do you find any suggestion that a carbonized *thread*, or in fact any *filament* of carbon, would occlude so much air or other gas as to make it impossible to secure the high vacuum by the use of the Sprengel pump alone, and without resorting, in addition thereto, to the use of electrical heating of the filament?

A. I find no statement of any kind, made prior to the date of the patent in suit, concerning carbonized thread or carbon filament burners. The patent in suit states that "there must be almost a perfect vacuum to render the carbon stable, *especially* when such carbon is *small in mass* and high in electrical resistance"—thus calling particular attention to the interdependence between a very high vacuum and such carbon. In view of this statement in the patent in suit, and those contained in the Sawyer & Man patents before referred to, regarding the necessity of removing occluded gases from the carbon burner and lamp chamber, I think that the art would have at once recognized that the carbon would not be stable, unless the occluded gases were driven out of the burner by electrical heating, and withdrawn from the lamp chamber by exhausting it to a very high degree.

408 x-Q. I do not ask you whether the art would or would not have thought the *carbon would be stable* without the electrical treatment, but whether the art on reading the patent in suit on the day of its issue, would have known that it was necessary to make use of electrical heating of the carbon during the exhausting of the globe *in order to secure a high vacuum?*

A. I think so.

409 x-Q. Do you also think that the art, at the date of the patent in suit, would have known, with the knowledge then possessed by the art and without invention, how to make use of the process of electrical heating, in connection with a carbon filament such as is referred to in the patent?

A. Yes.

410 x-Q. How do you account for the fact, then, that more than two years later Mr. Edison (upon an application filed in December, 1880) procured a patent for the electrical treatment of the carbon burner of an incandescent lamp during the process of exhausting the globe—I refer to the Edison Patent No. 265,777 of October 10, 1882?

Objected to as immaterial and incompetent.

A. I know nothing about it, nor of the nature of the invention described and claimed in that patent. I simply hold the opinion that at the date of the patent in suit it would not have required invention to electrically heat the burner during the process of exhaustion, and obtain a very high vacuum, which would result in the burner being durable enough for practical commercial purposes.

411 x-Q. In the case of a carbon filament, what difference would it make in the degree of vacuum obtained whether electrical heating of the carbon were resorted to during the exhausting of the globe or the globe were exhausted without this? I assume, of course, that the most efficient pump be employed, and that the highest attainable vacuum be secured in both cases.

A. I cannot answer this question in exact terms, but can state generally that if the globe is exhausted without heating the burner the vacuum is so low that the burner is soon destroyed; while on the other hand, the vacuum obtainable with electrical heating is so high that the burner enclosed in it is durable.

Adjourned for lunch.

Resumed.

412 x-Q. *With* electrical heating would it, in your opinion, be possible to obtain a vacuum as high as that which is mentioned in the patent in suit, viz., one one-millionth of an atmosphere?

A. I think so, although I recall no data based upon experiments in this direction made upon incandescent lamps since the date of the patent in suit. But I believe that in experiments made with vacuum tubes a considerably higher vacuum than this has been obtained, and I see no reason why the vacuum of an incandescent lamp could not be made as high as that mentioned in the question.

413 x-Q. *Without* the electrical heating could the vacuum, in your opinion, be made one-half as high as *with* the electrical heating, assuming the carbon burner to be of filamentary size?

A. I do not think so.

414 x-Q. Could it, in your opinion, be made one-tenth as high?

A. I do not know whether long-continued exhaustion of the globe would produce this result or not, not being in possession of any experimental facts upon this point to assist me in forming an opinion.

415 x-Q. Let me call your attention to certain facts which, it seems to me, ought to aid you in forming an opinion. There are in evidence certain of the Edison lamps, made presumably under the patent in suit; also there is a table giving the dimensions of the carbons in these lamps. I think that you will find that the cubic contents of one of the globes of the 16-candle-power lamps is some thousands of times the cubic contents of the burner in such globe. Now, do you think it reasonable to suppose that the removal from the carbon by electrical treatment on the pump

of *all* the air and oxygen occluded in the carbon (even if it were possible to remove all) would enable one to produce in the globe a vacuum ten times as high as that which could be produced by the pump without the aid of the electrical heating, even if we assume in this latter case (contrary to what I suppose the fact to be) that the pump would remove only such air and oxygen as *surround* the carbon within the globe, and none of that which is *occluded within* the carbon?

Objected to as indefinite and argumentative.

A. I think that this could be reasonably supposed, although I cannot state the ratio of the vacua obtained in these two ways. While a high vacuum may be produced by the process of exhaustion alone, a large amount of gas still remains occluded in the carbon, held there by some attraction which apparently can only be overcome by the application of heat. Now, if the globe were exhausted without electrical heating, and the lamp were used in this condition, these gases would be expelled from the burner, resulting in a lowering of its vacuum to a considerable extent as compared with that of a lamp in which these gases have been driven out of the burner and withdrawn from the globe. The relative volumes of the carbon burner and the space enclosed in the globe do not, I think, have an important bearing on this question, in the absence of information concerning the ratio between the volume of the carbon and the volume of the gas contained in it.

416 x-Q. It is, then, your opinion that the amount of air or oxygen occluded in one of the carbon burners of an Edison 16-candle-power lamp, prior to its introduction into the globe, is so great that if the globe were exhausted to the highest attainable vacuum without electrically heating the carbon, the subsequent application of the process of electrical heating to such carbon would reduce this vacuum more than to one-tenth of what it was before?

A. I cannot say, because I have no data on which to base an opinion with the exactitude called for in the question.

417 x-Q. I did not intend to tie you down to *exact* figures. Instead of "one-tenth" (the figure named in my last question), you may make the ratio, if you please, *one-fifth* or *one-fifteenth*. With this variation dare you venture an *opinion* upon the question?

A. Yes, in another manner, but not in ratios, as I have already stated in answer to 411 x-Q. In my opinion there will be such a reduction in the vacuum by electrical heating, that if the burner is used in this lower vacuum, it will not be durable as compared with the life which it would have if after this electrical heating the gases were pumped out of the globe and the vacuum again made high.

Adjourned until September 30, 1890, at 11 A.M.

September 30, 1890.

Met pursuant to adjournment, at the office of Betts, Atterbury & Betts, 120 Broadway, New York.

Present Counsel as before.

Cross-examination of Witness, Charles L. Clarke, continued:

418 x-Q. The facts, then, as they lie in your mind, seem to be about these: that with a filament of carbon such as is used in an Edison 16-candle-power lamp, you could with a Sprengel pump exhaust the globe to a high vacuum without electrically heating the carbon; but that the amount of gases occluded in the carbon is such that if electrical heating be applied after the vacuum is formed, these gases will be driven out into the globe and thus lower the vacuum, and, unless removed by subsequent pumping, will act upon the carbon to quickly destroy it. With this statement of the facts, is your test of what constitutes a "high vacuum" the ability of the carbon to endure the passage of the current for a practically long period of time?

A. Yes. I should consider that for electric lamps such a vacuum would be properly considered as high.

419 x-Q. And also that a vacuum which would not give durability to the burner would necessarily be low?

A. It would be low in the sense in which that expression is applied to the vacua of modern incandescent lamps.

420 x-Q. Do you then hold that in the art of incandescent lighting it is the durability of the carbon that furnishes the test whether the vacuum be high or low, and that it is not the absolute degree of exhaustion of the globe that constitutes such test?

A. Not exactly this. In my opinion the vacuum in which a carbon burner is practically durable is high enough to be properly called a "high vacuum," while a vacuum in which the carbon will not be durable is properly called a "low vacuum" in the sense that it is so low as to prevent the carbon from being durable.

421 x-Q. If you could exhaust the globe of a carbon lamp to the one one-millionth of an atmosphere without electrically heating the carbon during the operation, would that be a high vacuum or a low vacuum?

A. That would be a high vacuum so long as it lasted.

422 x-Q. In like manner, if you secured a vacuum of one one-hundred-thousandth of an atmosphere without electrically heating the carbon of the lamp, would that be a high vacuum?

A. I think so, assuming this to be possible.

423 x-Q. Do you think it possible with such a lamp as the Edison 16-candle-power lamp?

A. I think that with long-continued exhaustion, and the additional precaution of keeping the lamp and all the parts connecting it to the pump at a constant temperature, this vacuum might possibly be obtained; but such a method of procedure would, I think, be entirely impracticable to carry out, and would not subserve any useful purpose, for any rise in the temperature, and particularly the heat generated when the lamp was used, would drive out gases, not only from the carbon burner, but also from all the interior parts of the lamp globe, and destroy the practical value of the vacuum, as compared with that of the vacuum which the art ought to produce by electrical heating during the process of exhaustion.

Adjourned for lunch.

Resumed.

424 x-Q. In the practice of the electrical heating of the carbon burner, is it necessary that the temperature be carried to a higher point than that at which the burner is to be run in the practical use of the lamp?

A. I believe so.

425 x-Q. In connection with this matter of electrical heating of a carbon burner during the process of exhausting the lamp globe, you have referred to Edison's English and French patents of 1879; so far as those patents deal at all with the electrical treatment of carbon, do they not speak of carbon "sticks" and "pencils" ("crayons"); and is it not represented in those patents that the object of such treatment is, not to produce a better carbonization of the material of the stick or pencil, but to free the stick or pencil from air in order to make it "very homogeneous and hard"?

A. Yes; although one result of this process would be to produce a better carbonization.

426 x-Q. Do you understand that the "carbon sticks" and "carbon pencils" referred to in the Edison British and French patents were made out of fibrous material which had been only partially carbonized in a carbonizing furnace?

A. No; the expression is a general one, not limited to the particular kind of carbon referred to in the question.

427 x-Q. If these sticks or pencils were made from the deposited carbon of the gas retort, would not the material composing them be fully carbonized?

A. I think so; of course I did not mean to say, in my answer to 425 x-Q., that this process would result in the better carbonization of a stick already perfectly carbonized.

428 x-Q. Well, is there anything in these Edison patents to indicate that Mr. Edison understood that his electrical treatment of a carbon stick or pencil—or for that matter, of carbon in any shape—would be useful by way of perfecting the carbonization of the material subjected to the process?

A. Apparently not.

429 x-Q. Is there anything in those patents to indicate that the carbon sticks or pencils were intended by Mr. Edison to be used as the burners of incandescent lamps?

A. There is nothing in these patents specific on this point; the process is described as applicable to carbon sticks broadly, and I take it that they are to be used for any purpose to which they are suited.

Adjourned until October 1, 1890, at 11 A. M.

OCTOBER 1, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

430 x-Q. At various places in your testimony you have asserted, or assumed, that "the process described in the patent in suit" necessarily results in the production of a carbon of *high* specific resistance. What are the special features of this process by virtue of which the specific resistance of the carbon composing the burner is *high?*

A. I had in mind the description in the specification of the process of bringing the carbonizable material, such as the mixture of lampblack and tar, cotton and linen thread, wood splints, paper, etc., into the desired size and shape, before its carbonization in the furnace.

431 x-Q. Simply that, and nothing more?

A. No. The process would not be completed, of course, until the material was carbonized. I should have mentioned that in my last answer.

432 x-Q. Then, as I understand you, you consider it to be the teaching of this patent, that shaping the burner *before* carbonization necessarily results, on carbonization, in a *high* specific resistance, as compared with that of a burner formed by shaping *after* carbonization?

A. What the patent teaches in this respect I cannot say. I simply hold the opinion that if this process is carried out, it will result in the production of a carbon of high specific resistance.

433 x-Q. Do you hold that the *high* specific resistance, which you say necessarily results from the process of the patent in suit, *is due to the fact* that the burner is to be shaped *before* carbonization?

A. Yes; because the shaping necessitates the employment of those materials which will become of high specific resistance when carbonized.

434 x-Q. Would not those same materials have the same high specific resistance if carbonized without being first shaped into the form of a burner?

A. Whether they would have absolutely the *same* specific resistance or not, I do not know; although undoubtedly they would be of high specific resistance.

435 x-Q. So far as you know, might not the specific resistance be higher if these materials were carbonized before shaping than when the shaping preceded the carbonization?

A. I am in possession of no facts to aid me in forming an opinion upon this point.

436 x-Q. Do you, then, answer the question in the affirmative?

A. I simply do not know, as I have already stated.

Adjourned for lunch.

Resumed.

437 x-Q. Do you regard this shaping before carbonization as the main feature of the process described in the patent?

Objected to as incompetent and immaterial.

A. I do not know what is meant by the expression "main feature," as used in the question. I simply find this shaping described in the specification as a part of the process which is to be carried out in the manufacture of the incandescent lamp.

438 x-Q. Please explain how you are warranted in the conclusion that the *high* specific resistance of the carbon burner of the patent in suit depends upon the fact that the burner is shaped *before* carbonization, when you admit (as in answer to 434 x-Q.) that a high specific resistance will be secured if the carbonization precedes the shaping.

A. The high specific resistance depends upon or follows from the fact that the burner is shaped before carbonization, because the materials which can first be reduced to size and shape will have a high specific resistance when carbonized. If I understand the last part of the question aright, it does not correctly represent my position when answering 434 x-Q. I understood that question to refer to the specific resistance which carbon would have as a result of carbonizing the material in bulk, and to nothing beyond this, such as producing a burner of the required size and shape by forming it out of the carbonized material; a method of procedure which, in my opinion, would be a practical impossibility, and which, I think, warrants the conclusion that the high specific resistance of a carbon burner, made by the process described by the patent, depends upon shaping before carbonization.

439 x-Q. Apparently, then, you consider that the "high specific resistance" of the patent does not result alone from the fact that the burner is shaped before carbonization, but, in addition to this, depends upon the fact that it is brought into the *filamentary* form before carbonization; do you so hold?

A. I know nothing of the bearing of the patent upon the points inquired of in the question. But as to the high specific resistance which results from carrying out the process described in the patent, it does not, in my opinion, depend upon the size of the burner, in addition to shaping before carbonizing.

440 x-Q. Do you, then, hold that the high specific resistance of the patent is independent of the size to which the burner is brought before carbonization?

A. Assuming that the question refers to the process described in the patent of manufacturing a carbon burner, in my opinion the carbon of such a burner would be of high specific resistance, independent of the size to which it is brought before carbonization.

Adjourned until October 2, 1890, at 11 A. M.

OCTOBER 2, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

441 x-Q. If, as your last answer admits, the high specific resistance of the burner of the patent in suit is independent of the size to which it is brought before carbonization, how can it be, as you assert in answer to 433 x-Q., that this high resistance is due to the fact that the burner is to be shaped before carbonization?

A. Because the patent directs one to bring the material to the desired size and shape before carbonization, which I believe is the only practical method to pursue in constructing the burner for an incandescent lamp, and refers to certain materials with which this result can be accomplished, all of which materials, as well as any others suitable for the purpose, would, I think, upon carbonization, produce a carbon of high specific resistance.

442 x-Q. Do you know of any carbonizable material which, on being fully carbonized, would not give a carbon of high specific resistance; assuming, of course, that it is not subjected to any treatment subsequent to carbonization, whereby its specific resistance would be lowered?

A. I cannot state whether or not there is any material which, upon being fully carbonized, would give a carbon which would not be of high specific resistance. But for the manufacture of incandescent burners, I cannot call to mind any material which could be reduced to size and shape, before carbonization, which would yield a carbon not of high specific resistance.

443 x-Q. I wish to make my question a little more generic. Do you know of any carbonizable material which, upon being carbonized—whether for the purpose of being used for burners of incandescent lamps or otherwise, and whether or not it be first reduced to a form suitable for the burner of an incandescent lamp—will not give a carbon of "high specific resistance," as you have been using this term in relation to the patent in suit? I of course assume, as before, that the product is not submitted to any process subsequent to the carbonization whereby its resistance is reduced.

A. No; understanding that the exclusion of any subsequent treatment refers to either the hydro-carbon treatment or impregnation with a carbonizable liquid and subsequent recarbonization, or electro-plating with copper, and that gas carbon is also excluded. If the question refers to carbon which may result in *any* way from carbonizing a material, thereby including gas carbon, from which the burners of some of the early lamps were made, then I answer yes; which answer, upon the same assumption, applies to the last question.

Adjourned for lunch.

Resumed.

444 x-Q. In 12 Q. you were asked your opinion as to

whether there was invention "in substituting the carbon burner of the patent in suit for the platinum burner of Edison's patent No. 227,229." In your answer you say that you do not think that in April, 1879, any one would have thought it possible to substitute "a carbon *wire*" in place of the platinum wire of said patent No. 227,229; and you also say, in substance, that the construction of a lamp which made it possible, by taking advantage of a certain alleged newly-discovered property of carbon, to use a "carbon burner of *filamentary form*," was an invention of great merit, etc. Did you, in thus answering, regard the term "carbon *wire*" as synonymous with the expression "carbon burner of *filamentary form*?"

A. I used the term in that sense.

445 x-Q. In thus using the word "wire," you regarded a *carbon wire* as being "the carbon burner of the patent in suit," referred to in 12 Q., did you not?

> Objected to on the ground that counsel has interrogated the witness over and over again as to every possible phase of his answer to 12 Q.

A. No, if I understand the question aright I only had in mind carbon burners made by the process described in the patent in suit, and the fact that carbon wires—or carbon burners of filamentary form—are made by this process.

446 x-Q. Did you then, in answering interrogatory 12, express any opinion upon the real question therein submitted to you, namely, whether there was "invention in substituting the carbon burner of the patent in suit for the platinum burner of Edison's patent No. 227,229, and corresponding foreign patents?"

A. Yes; as I understood that question.

447 x-Q. In answering 12 Q. what did you understand the expression "the carbon burner of the patent in suit," contained therein, to mean?

A. Carbon burners made in the manner described in the specification.

Adjourned until October 3, 1890, at 11 A. M.

New York, October 3, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

Cross-examination of the witness, Charles L. Clarke, continued:

448 x-Q. That simply changes the form of expression, but does not explain what you understood the original expression to mean. Please explain in detail what, in answering 12 Q., you understood to be the meaning of the words of the question "the carbon burner of the patent in suit?"

A. While that expression standing alone refers, as I understand it, to burners made by the process described in the patent, that being the only practical way in which burners can be made, I did not understand, in answering the question, that it was limited to burners made by this process—assuming that other practicable methods of making them were known or discoverable—for the reason that particular reference was made to questions and answers in Professor Cross' deposition in which carbon burners are considered without any limitations as to their mode of construction. I therefore considered this expression not to be limited to burners made by any particular process, and answered it accordingly.

449 x-Q. Still you do not explain what you at the time understood that expression to mean. Please do so?

A. As the expression is used in that question, taken in connection with the context, I understood it to mean "carbon burner."

450 x-Q. Do you mean carbon burner irrespective of size, or resistance, or illuminating power, or process of manufacture?

A. Yes.

451 x-Q. Do you then understand that the carbon burner of the patent in suit is unlimited as to size, and as to resistance, and as to the mode of manufacture?

> Objected to as incompetent and unwarranted

by the direct examination if the question is intended to call for a legal construction of the patent.

A. I do not know in what way the patent in suit may be limited or to what extent. The process therein described is at least applicable to the making of burners of the various sizes and resistances now used in modern lamps.

452 x-Q. In answer to 449 and 450 x-Qs., you say that you understood the expression "the carbon burner of the patent in suit," contained in 12 Q., to mean "carbon burner, irrespective of size, or resistance, or illuminating power, *or process of manufacture;*" and in answer to 447 x-Q. you say that you understood the expression to mean "carbon burners *made in the manner described in the specification*" (that is, of the patent in suit). How do you reconcile these two statements?

A. I have already stated, in answer to 448 x-Q., that while I did understand that the expression found in 12 Q. referred more particularly to carbon burners made by the process described in the patent, as that is the only practicable way of making burners, I understood from the context of 12 Q. that the expression was not to be limited to burners made by this process, but was intended to refer to carbon burners generally. Now, in answering 447 x-Q. I had in mind the fact that the only known process of making burners is that described in the patent in suit, and I considered and intended that my answer should include *all* burners.

Adjourned for luncheon.

Resumed.

453 x-Q. If the fact be, as you assume, that the process described in the patent is the only practicable way of making burners, how could you consider, if you did so consider, that the expression in 12 Q., "the carbon burner of the patent in suit," included burners made by some other process than that described in the patent, and burners which therefore, according to your judgment, would not be practical?

A. I have already answered this question in substance twice, to the effect that this expression, taken in connection with its context, referred to carbon burners broadly. I considered that the expression referred to burners in general, because that was what was asked by the question, and was the subject under discussion.

454 x-Q. When you say that 12 Q. "referred to burners *in general*," do you mean that you at the time understood it to refer to burners *other* than those made by the process described in the patent?

Objected to as having already been answered.

Defendant's counsel requests complainant's counsel to point out any place where this question has been answered.

Complainant's counsel calls attention to the answer to 452 x-Q.

A. I understood it to refer to burners in general, as a broad idea, irrespective of any particular process, so long as the result would be a practical burner.

455 x-Q. But you also understood at that same time, did you not, that it was impossible to make what you call a "practical burner," except by the process described in the patent?

A. Yes.

456 x-Q. Then I press my question, which remains unanswered, whether in answering 12 Q. you understood the expression "the carbon burner of the patent in suit" to refer to burners *other* than those made by the process described in said patent?

A. Yes, to burners made by any practicable process, such being assumed to exist or to be discoverable.

457 x-Q. To prevent any possible misunderstanding I will put my question in this way: Do you mean to

say that you understood Mr. Dyer, when, in Interrogatory 12, he questioned you about "the carbon burner of the patent in suit," to refer not only to burners made by the process of the patent in suit, but also to burners made by some other process?

A. I understood the expression to refer to any practical carbon burners, and, therefore, made by any practicable process known or discoverable.

Adjourned until October 4, 1890, at 10:30 A. M.

October 4, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

Cross-examination of the witness, Charles L. Clarke, continued:

458 x-Q. Then, of course, you desire to withdraw your answer to 447 x-Q., do you not?

A. No; but rather that it should be modified to plainly mean what I intended it to mean, and to include all that I had in mind, at the time I gave it, as explained in subsequent answers, to the effect substantially that while the *exact* words of the expression speak of burners made by the process described in the patent, I understood that, taken in connection with the whole question and the subject to which it related, specifically referred to therein, this expression was really intended to refer to burners in general made by any assumed practicable process.

459 x-Q. Then, really, the words of your answer to 447 x-Q., "carbon burners made in the manner described in the specification" (of the patent in suit), mean carbon burners *made by any process whatever*. Is that correct?

A. Yes, assuming a practicable process.

460 x-Q. Assuming, as you have said you do assume, that there is no other practicable process of making

carbon burners, do you still say that the words "carbon burners made in the manner described in the specification" (used by you in 447 Ans.), mean carbon burners made by any process whatever, including other processes than that described in the specification?

A. Yes, for reasons stated in answer to 458 x-Q.

461 x-Q. In other words, those words quoted from your answer to 447 x-Q. include not only burners made by the process described in the patent in suit, but also made by processes that are not practicable?

A. By no means. I have always assumed practicable processes, as can be gathered from many of my answers.

462 x-Q. How then can you say that your expression "carbon burners made in the manner described in the specification" (of the patent in suit) includes burners made by any other process than that described in the said specification, if you are sincere in your statement, repeatedly made, that there is no other practicable way of making carbon burners?

Objected to by complainant's counsel on the ground that the witness has several times explained his position on this matter, and answered questions substantially like this. Complainant's counsel again protests against the apparently unnecessary protraction of the cross-examination.

Defendant's counsel states that he deems it unnecessary, by way of relieving himself from the imputation contained in the foregoing remark, to do more than refer to the record itself, from which it will abundantly appear that, if the cross-examination has been unnecessarily prolonged, the fault does not lie with defendant's counsel.

Defendant's counsel desires to state that he has thus far patiently and uncomplainingly (so far as the record is concerned) submitted to the peculiar methods of the witness, although it has involved an expense and a consumption of time that has been onerous in the extreme. He had hoped that complainant's counsel, knowing where the real difficulty lies, would have withheld from the record suggestions which impliedly charge defendant's counsel with the responsibility for the prolongation of this examination. As, however, he has chosen to adopt a different course, the above explanation seems to be in order.

Complainant's counsel replies that he cannot agree with defendant's counsel that the protraction of the cross-examination is wholly due to the witness, since he believes that the cross-examination should have been closed weeks ago, judging from the fact that defendant's counsel has apparently been going again and again over the same ground upon which he has already exhaustively cross-examined the witness. Complainant's counsel is therefore compelled to believe that the continuance of the cross-examination will not lead to the further elucidation of any of the issues of the case.

Defendant's counsel gives notice that he proposes to continue the cross-examination of this witness as long as may be necessary to secure answers that are responsive to the subjects of his inquiries, and if this necessitates the recurrence to branches of the case already partially investigated, but where the witness has evaded making answers that were responsive to the interrogatories propounded, he knows of no rules of evidence or of practice to prevent.

A. For the reasons given in answer to 453 x-Q. which, as I understand it, asks substantially the same question.

Adjourned for lunch.

Resumed.

463 x-Q. You hold, I believe, that "the process of the patent in suit" involves the reduction of the carbon to shape before carbonization?

A. That is a part of the process described in the patent for making a burner.

464 x-Q. Does the "process of the patent in suit" also involve the reduction of the carbon to *filamentary form* before carbonization?

A. No, understanding that the question refers to what can be done by means of the process described in the specification. Larger burners can be made by this process.

465 x-Q. I notice that in your last two answers you have adopted the phraseology "the process *described in* the patent," while in my questions I used the phraseology "the process *of* the patent," etc. Did you, in the last two answers, use the modified form of expression, thinking that it meant something different from the expression used in the questions?

A. I thought from the way in which this expression was used in the questions, in connection with the context, that unless I referred definitely to the process described in the specification, my answers might be construed as being the expression of an opinion upon the legal limitations of the patent with respect to the process referred to.

Answer obected to as not responsive.

466 x-Q. (Question repeated.)

A. No.

467 x-Q. Do you mean by the later portions of your testimony to leave upon the mind of the Court the impression that in 12 Q., as you understood it at the time it was asked, complainant's counsel did not call upon you to consider the patent in suit, and to consider specially the process of making an incandescent lamp which is therein described?

A. Yes. I understood that the question referred to the substitution of a carbon burner in place of a platinum burner in an all-glass lamp chamber containing a high vacuum, irrespective of anything contained in the patent in suit.

468 x-Q. Did complainant's counsel in any other than in 12 Q. call upon you to consider the patent in suit, and to consider specially the process of making an incandescent lamp which is therein described?

> Objected to as indefinite, unless the counsel calls the attention of the witness to some particular question, the answer to which he desires explained.

A. No, not that I remember, excepting to consider certain statements made in the patent with respect to the prior state of the art of incandescent lighting.

469 x-Q. You refer, I suppose, to 11 Q.?

A. Yes.

470 x-Q. Did complainant's counsel in 11 Q. call upon you to consider the process of making a lamp which is described in the patent in suit?

A. Not as I understood the question.

471 x-Q. In view of your last four answers, please explain what you meant in answer to 276 x-Q. where you said: "I have not been asked by the complainant to consider the patent in suit, excepting as to the description of the lamp *and the process of making it*" (italics mine)?

A. The use of the expression "excepting as to the description of the lamp and the process of making it," which appears in the answer to 276 x-Q., was not a correct statement, as evidently appears from the questions asked me by complainant's counsel upon my direct examination. Up to this point in my cross-examination I had been asked many questions concerning lamps made by the process described in the patent, and without reviewing my direct examination, I inadvertently stated that the latter contained questions of the same limited character as those contained in my cross-examination.

Adjourned until Monday, October 6, 1890, at 10:30 A. M.

October 6, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

Cross-examination of the witness, Charles L. Clarke, continued:

472 x-Q. In your answer to 273 x-Q. you say: "The invention described in the patent in suit solved the problem of subdivision, because it instructed the art how to make lamps adapted for use in multiple arc," etc. Did you make that assertion on the assumption that the patent in suit contains the earliest description of a method of making carbon burners whereby they can be made so small that their total resistance will be so great as to adapt them for economical use in multiple arc?

A. Not exactly, but that, as I believe, the patent for the first time describes a practical incandescent lamp, the burner of which is made by a process suitable for making burners small enough and of high enough resistance to adapt them for use in multiple arc.

Adjourned for lunch.

Resumed.

473 x-Q. Did you in point of fact assume, at the time you made the assertion quoted in the last question, that the patent in suit contains the earliest description of a mode of making carbon burners whereby they can be produced of such size and resistance as to adapt them for use in multiple arc?

A. No.

474 x-Q. Then that assertion of yours, quoted from your answer to 273 x-Q., is predicated upon instruction which the patent in suit gives in regard to the *lamp construction*, and not upon the instruction which it gives in regard to the mode of making the

burner to be used in such lamp structure. Is this correct?

A. No. I think that it was important that the patent should describe a method suitable for making small burners of high resistance, and refer to the fact that such burners would be stable in a high vacuum.

475 x-Q. Do you mean that this was necessary because there was no such method known to the art at the time?

A. No.

476 x-Q. Do you then assume that such method was known to the art?

A. Yes.

477 x-Q. If a method of making small carbon burners suitable for use in multiple arc was known to the art prior to Mr. Edison's invention which forms the subject of the patent in suit, why was it necessary for this patent to describe such method, in addition to describing the *lamp construction* which, as I now understand you, constitutes the real *invention* of the patent?

A. As to what the real invention of the patent may be, I do not know. I simply find in it a description of a lamp construction, as well as methods to be pursued in making different parts of the lamp.

478 x-Q. I am not now asking you what constitutes the invention of the patent; but why, in describing a *lamp construction* (which, from various things contained in your deposition, I understand you to regard as the real invention made by Mr. Edison) you should deem it necessary for the patent to describe, in addition to such lamp construction, an old method of making carbon burners whereby burners could be produced of such size and resistance as to be adapted for use in multiple arc?

A. Prior to the date of the patent in suit, more than one method of making carbon burners was known, and I therefore think that it was important that, with impracticable methods in existence, the practicable method should be ascertained and announced.

Adjourned until October 7, 1890, at 10:30 A. M.

October 7, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

Cross-examination of the witness, Charles L. Clarke, continued:

479 x-Q. Do you mean to intimate that there was "more than one" method known to the art prior to Mr. Edison's invention, whereby carbon burners could be made of such size and resistance as to be adapted for use in multiple arc?

A. No. I believe that there was only one method in existence by which it would be possible to make such burners, although, prior to the date of the patent in suit, I do not know that any such burners had been made by this method.

480 x-Q. And that one method was the method described in the patent in suit, was it not?

A. Yes.

481 x-Q. In answering the last question but one, you seem to lay special emphasis upon the alleged fact that, although the method of making carbon burners which is described in the patent in suit, was known to the art prior to Mr. Edison's invention, yet no burners had been made by this method which were of a size and resistance that specially adapted them for use in multiple arc. Do you regard such fact, if such fact exists, as a special reason why it was necessary or important that the Edison patent should describe this old process?

A. Yes. I consider that it was important on that account.

482 x-Q. For a similar reason would you not think it important that the patent should describe the process of electrical heating of the carbon burner while on the pump; which process I understand you to claim to have been old at the date of Mr. Edison's invention, but not to have been applied to any burners of such size and resistance as adapted them for use in multiple

are, nor, for that matter, to the burners of any durable and practical lamp?

A. No. I see no reason why the patent should call attention to the process of electrical heating in any more explicit way than it has. There was but one such process known, and I think that the known desirability of removing the occluded gases from the burner, as well as the references in the patent to an almost perfect vacuum, would have led the art to at once make use of electrical heating.

483 x-Q. Did not this alleged old process of the electrical heating of the burner differ from that process which is actually used in the practical manufacture of lamps in at least one important and necessary particular, namely, that in practice it is necessary that the temperature of the burner during the process be raised to a point very much higher than that to which it is to be subjected in actual use, while in the old process of electrically heating a carbon this high temperature was not secured?

A. Assuming that it is necessary to carry this temperature to as high a degree as is indicated in the question, in order to make a practically operative lamp, which I now do not understand to be the fact, I think that the literature of the art prior to the date of the patent in suit gave such instructions. For I find in Sawyer & Man's United States Patent No. 210,809 that: "To drive these out (occluded gases) we pass an electric current through the conductors *x x*. The carbon pencil M, is *intensely* (italics mine) heated, and considerable heat having extended throughout all the inclosed material, thus driving out occluded gases, the operation of exhaustion and refilling with nitrogen is continued until finally all the elements of danger are eliminated from the lamp." Again Edison's English and French patents for a platinum lamp, before referred to, described the process of electrical heating in connection with driving out occluded gasses from a platinum-wire burner, and obtaining a nearly perfect vacuum, and state that, as a part of the process, the temperature of the platinum burner is to be raised "* * * until

it attains *vivid* incandescence" (italics mine), and, in addition, call attention to the fact that "carbon sticks may be also freed from air in this manner, and brought to a temperature that the carbon becomes *pasty* (italics mine), and if then allowed to cool is very homogeneous and hard." I think that the instructions contained in these patents to heat the carbon *intensely*, and until it becomes *pasty*, in order to drive out occluded gases, and to heat a platinum burner to *vivid* incandescence for the same reason, and to obtain a high vacuum, amount to an instruction to bring the temperature of the burners to a higher degree than that at which they would be normally operated.

484 x-Q. Do you understand that Mr. Edison in his French and English patents intended by the expression "vivid incandescence," or anything else therein contained, to indicate that the platinum burner was to be raised to a higher temperature during the electrical treatment than that to which it was to be subjected in subsequent use? In this connection I again invite your attention to the Edison United States Patent No. 265,777, of October 10, 1882, in which he indicates, as a necessary difference in the application of electrical heating to a carbon burner and to his older platinum burner, that in the case of the carbon the temperature during the treatment should be carried to a higher point than that at which the completed burner is to be used.

Objected to as having been already answered more than once by this witness.

Defendant's counsel desires to know where.

Complainant's counsel calls attention to the answer to 483 x-Q.

A. I know nothing concerning the nature of the invention as described and claimed in the patent particularly referred to in the question, but hold the opinion that upon reading the patent in suit good skill and judgment would lead the art, in view of the instructions contained in Mr. Edison's French and English platinum lamp patents, to bring the burners, during the process of electrical heating, to a higher temperature than that at which they would be brought when in use.

Answer objected to as not responsive.

485 x-Q. (Question repeated.)

A. Yes. I believe that the instruction contained in the Edison patent referred to, concerning the application of the process of electrical heating for the purpose of driving occluded gases out of the burner, and to obtain, in connection therewith, a nearly perfect vacuum —a process which was to be continued up to a point at which the burner would be at "vivid incandescence"— was an instruction to heat the burner until it had attained the highest temperature possible without danger of its melting, a temperature which it would not be practically safe to approach when the lamp is in ordinary use.

Adjourned for lunch.

Resumed.

486 x-Q. Are Edison's French and English patents more explicit in regard to the temperature to which the platinum burner is to be carried during the electrical heating on the pump than is his United States Patent No. 227,229?

Objected to on the ground that the patents show for themselves.

A. Apparently not. The instructions in the three patents referred to seem to be of substantially the same import.

487 x-Q. Do you think that you are in better condition to judge of the temperature to which Mr. Edison designed to carry his platinum burner during the electrical heating of it than he was himself when he took out his Patent No. 265,777, of October 10, 1882?

Objected to as immaterial and irrelevant and as assuming a construction of Patent No. 265,777, which is not supported by that patent.

A. I suppose not, although I fail to see what bearing Mr. Edison's designs have on the patent. As I understand it the patent speaks for itself.

488 x-Q. It is a fact, is it not, that Mr. Edison, in his patent for the electrical treatment of a carbon burner, to wit, the aforesaid patent, No. 265,777, represents that this process of electrical heating, as applied to a carbon burner, is materially different from the process as applied to a platinum burner?

A. He states that there is a difference between them.

489 x-Q. Are you not aware of the fact that, in order to bring a platinum wire to incandescence, it must be heated to a point very near that of fusion?

A. I do not know what is meant by the expression "very near." I would like to have the question more definite on this point.

490 x-Q. Say within 200° Fahrenheit?

A. Yes. With only this difference, the platinum wire would be brought up to a bright incandescence. My answer is based upon the assumption that the platinum wire has not been electrically heated during the process of exhausting the lamp globe, which, I understand, would result in very materially raising the temperature of its melting-point.

Adjourned until October 8, 1890 at 11 A. M.

October 8, 1890.

Met pursuant to adjournment.

Adjourned until October 9, 1890, at 11 A. M.

October 9, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

Cross-examination of the Witness, Charle L. Clarke continued:

491 x-Q. In answer 12 you speak of what you call "a newly discovered property of carbon," which discovery you ascribe to Mr. Edison, and then you go on to say that, in your opinion, "the construction of a lamp which made it possible to take advantage of this property of carbon, and to use a burner of filamentary form, which made incandescent lighting commercially possible, was an invention of great merit and utility."

By this I understand that, in your opinion, it was the originating of a *lamp structure* which would permit of using a burner of filmentary form as well as larger sizes, rather than the discovery of a method of making burners of filamentary form, or the introduction of such a burner into the new lamp structure, that constituted "an invention of great merit and utility," and "made incandescent lighting commercially possible." What particular "*construction of lamp*" had you in mind in making the statement above quoted?

A. In answering 12 Q. I did not understand that I was called upon to consider one particular thing as being an invention rather than another, which appears to be implied in the present question; but that I was asked whether there was invention in substituting carbon burners in general, in lamp globes, like those described in Edison's platinum-lamp patents, before referred to, in place of platinum burners; to which I gave an affirmative answer, at the same time stating that this form of lamp construction permitted the use of filamentary burners, the same being the only burners which, at the date of the patent in suit, could, in my opinion, have been successfully introduced into and used in the lamp chambers referred to.

Answer objected to as irresponsive.

492 x-Q. In answer to 273 x-Q., you say as follows: "As I look at it, the invention covered by the patent (referring to the patent in suit) is for an incandescent lamp, possessing characteristics which make such lamps eminently adapted for use in multiple arc." What are the characteristics of the lamp to which you thus refer?

A. In that part of my answer to 273 x-Q. I was referring to the fact that the patent describes a lamp having a carbon burner enclosed in a high vacuum in an all-glass globe, and, further, describes carbon burners, filamentary in form, and of high specific resistance.

Adjourned for lunch.

Resumed.

493 x-Q. Do you, then, mean to say that, in using the language quoted from 273 A., you intended to say that "the invention covered by the patent" is for a lamp having a carbon burner enclosed in a high vacuum in an all-glass globe, said burner being filamentary in form and of high specific resistance? If not that, what do you mean?

Objected to as having been already answered.

A. I was not referring altogether to a lamp like that mentioned in the question, although such a lamp was included. I had also in mind a lamp having a carbon burner enclosed in a high vacuum in an all-glass globe, and also a similar lamp with a filamentary carbon burner, which are described by the patent, as I believe, for the first time.

Adjourned until October 10, 1890, at 2 P. M.

OCTOBER 10, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

494 x-Q. You say in your answer to the 12 Q. that Professor Cross could not in April, 1879, have determined the proportions necessary to be given to a carbon burner of an incandescent lamp. I wish, however, to ask whether the then state of the art was not such that Professor Cross, or any person skilled in the art, would have known that, if carbon was to be used as the material of the burner, it would necessarily have to be so shaped as to give a comparatively high total resistance, if the lamp was to be used for multiple-arc work, while for series work the carbon would have to be so shaped as to give a comparatively low total resistance?

A. I do not think that the state of the art, as it existed at that time, would have warranted any such conclusion, based merely upon a knowledge of the platinum lamp structure alone. If it had been suggested to use a carbon burner in this lamp globe, I believe that a person would have attempted to use a carbon rod like those used in lamps prior to that time, and would have met with failure in thus attempting to substitute a carbon for a platinum burner and would never have proceeded far enough to even consider the question of adapting the burners to use in multiple or in series.

495 x-Q. In other words, you think that, at the date in question, if it had been suggested to a person skilled in the art to use a *carbon* burner in the lamp globe of Edison's platinum-lamp structure, such person would not have known that the burner would have to be shaped differently if the lamp was designed for use in multiple arc, than if for use in series, so as in the former case to have a comparatively high total resistance, and in the latter case a comparatively low total resistance. Do you so hold?

A. Yes. I think that the history of the state of the art prior to that date warrants this assumption. Fontaine, in attempting to subdivide the electric light with incandescent lamps, made his experiments with lamps arranged both in multiple arc and in series, and in so doing made use of the same lamps in both case, without endeavoring to adapt the resistance of the burners to the conditions under which they were arranged in circuit. And up to the date of the patent in suit, the literature relating to the possibility of the subdivision of the electric light to which I have already referred in my direct examination, in which the problem was discussed in relation to lamps which were assumed to be alike as to their resistance, would, in my opinion, warrant the conclusion that in April, 1879, the art would not have known that the burners would have to be shaped differently to adapt them for use in multiple arc or in series. Moreover, it being the fact that carbon-rod burners had been used altogether up to that time which were found to be without stability, and the conditions under which stability was to be obtained being entirely unknown, I believe, for this reason also, that no one would have known that the burner would have to be of high resistance to adapt it for use in multiple arc, inasmuch as that would require a long and thin burner which would have then been deemed entirely impracticable. I do not think that the idea of the possibility of making a high resistance carbon burner would have occurred to a person.

496 x-Q. Would you have answered the last question any differently if the date referred to therein, instead of being April, 1879 (which is the date named by you in your answer to 12 Q.), had been a date immediately following the publication of Mr. Edison's French patent on the platinum lamp, to wit, June, 1879?

A. Leaving out of account the fact that carbon was supposed to have no stability; that the conditions under which it would be stable had not been ascertained; that of the processes of making burners, that one suitable for making them of high resistance and stable had not been found out; and that, as I believe, a person would have naturally first attempted to place a carbon-rod burner in the lamp chamber, an attempt which, I think, would have resulted in failure; and, further, that no one would, in my opinion, have thought that there would be any advantage in placing a carbon burner in an all-glass lamp chamber, but would, on the contrary, have considered the old lamp chambers made with separable parts as a superior form of construction; I will say that, if it were suggested to a person to place a carbon burner in the all-glass lamp chamber at the date mentioned in the question, he would, in my opinion, know as a matter of abstract reasoning that this burner should be of high resistance. As I look at it, however, no one would ever have been led naturally to consider this question of substituting a carbon burner in place of the platinum burner, or of making such a carbon of high total resistance.

Adjourned until October 11, 1890, at 11 A. M.

OCTOBER 11. 1890.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, CONTINUED:

497 x-Q. Do you then hold that in June, 1879, a person skilled in the art of electric lighting would have known that, if carbon was to be used as the material of the burner of an incandescent lamp, the total resistance of the burner should be comparatively high in order best to adapt the lamp for use in multiple arc, and comparatively low in order best to adapt the lamp for use in series?

A. Yes; I think that his knowledge then would have led him to understand that, aside from the supposed impossibility of making such burners which would be

durable, for multiple arc work they would have a comparatively high resistance, and for series work a comparatively low resistance.

498 x-Q. And would not such person naturally have sought to secure this difference in the burners (assuming, of course, that he had faith enough in carbon to experiment with it at all) by making the proportions of the burner different for the one class of lamps from those adapted for the other class?

A. No. I think that even if such person had had faith enough in carbon to experiment with it, he would at once have condemned its use for burners of high resistance as being manifestly impracticable, and would have been naturally led away from any experiments in this direction, and have confined his attention to improving the durability of carbon-rod burners which, under any circumstances, would only be suitable for use in series by improving the character of the carbon. Moreover, I believe that he would have experimented on these rod burners in an inert gas contained in separable lamp chambers similar to those which had been used prior to that time, which would have resulted in failure, and would have prevented even the suggestion of making the burners of high resistance. I feel strengthened in my opinion by the history of the art of electric lighting after Edison invented his platinum lamp; for although the invention was given world-wide publicity in the scientific journals, after the publication of his French patent, and the advantages of a burner of high resistance when used in multiple arc thus became known, no one appears to have been led, in view of this knowledge, to attempt to make burners of high resistance out of carbon; but, on the contrary, when a description of Edison's carbon lamp with a burner of high resistance was announced to the public, several scientists at once condemned it as an absolutely impracticable lamp.

499 x-Q. A fair interpretation of my last question would have assumed that the experimenter had faith enough in the use of carbon to make not only lamps adapted for series work, but also lamps adapted for

multiple arc work. Please answer the question thus interpreted?

A. Even upon this assumption, which I cannot at all admit as being justified by the history of the art, I do not think that a person would have attempted to secure this difference in the resistance of the burners; because, as I look at it, such person would, at most, only have had faith in gas carbon, which I believe the art at the time commonly held to be the most suitable kind out of which to make burners. Burners had to be made from this material by cutting and filing, a method which would have been recognized as impracticable for making burners of high resistance, and which, in my opinion, would not have been attempted.

500 x-Q. How, then, would he have proceeded under the assumption of the question to have made a part of the burners (to wit, those adapted for multiple-arc lamps) of comparatively high resistance, and the others (to wit, those adapted for series lamps) of comparatively low resistance?

A. If, as I now understand it, the question assumes that the person had at least faith enough to actually make an attempt to construct these burners, I think he would have tried to make them out of gas carbon by varying their proportions.

501 x-Q. Making the one class of burners thinner, and the other thicker, I suppose?

> This line of examination is objected to by counsel for the complainant as being immaterial and irrelevant, the questions obviously being based upon assumptions which are contrary to the facts.

A. Yes, bearing in mind the facts, as I believe, that the thinner burners never would or could have been made, and that no one would have had faith in carbon to attempt it, it being then understood that it was necessarily subject to rapid destruction when heated to incandescence, and the conditions under which it would be stable being then unknown.

> All of the foregoing answer after the word yes is objected to, as is also like matter contained in all the answers of the witness during the present session, as not being responsive to the questions, and as involving an unnecessary consumption of time.

502 x-Q. What physical property does a *filament* of carbon have by virtue of which it is adapted for use as the burner of an incandescent lamp, which a rod of carbon does not also have?

A. Contrasting the carbon rods which were used in the old lamps with the filamentary burners of modern lamps, the former were rigid, while the latter are flexible and elastic.

503 x-Q. My question did not limit you to a comparison of the carbon rods "used in the *old* lamps" with the so-called filaments of "*modern* lamps," but plainly was broad enough to include a comparison of the smaller burners used in modern lamps and the largest burners used in modern lamps, which you have heretofore said were so large as to be "rods." Please answer the question with reference to these two latter classes of burners.

Objected to as immaterial and irrelevant.

A. I do not understand that the rods and filaments used in modern lamps have any different physical properties, but only that the short and thick burners used in some of the series lamps are very much less flexible and elastic than the long and thin burners of the lamps commonly used in multiple arc.

Adjourned until October 13, 1890, at 11 A. M.

October 13, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

Cross-examination of the witness, Charles L. Clarke, continued:

504 x-Q. Referring once more to Fontaine's experiments, to which you have made frequent reference, is it not a fact that he used a battery power that was insufficient to bring the five lamps with which he experimented up to a vivid incandescence at the same time?

A. Yes. He purposely did that.

505 x-Q. Suppose at the present time a person were to employ a battery capable of supplying just enough current to bring one of the modern Edison lamps up to its normal incandescence, but were in fact to put five such lamps upon the circuit of such battery, would not the result be a smaller aggregate amount of light from the five lamps than he would get from one of them, if used alone on said circuit?

A. That would depend entirely upon the circumstances. If we assume that the battery is capable of supplying to a single lamp just the amount of current required to operate it at normal incandescence, and that the resistance of the lamp is high compared with the internal resistance of the battery, then five such lamps can be connected in multiple arc to the circuit of this battery, and the amount of current will increase so as to cause the total amount of light to be nearly five times the amount of light given by the single lamp when alone connected to the circuit. If, on the other hand, the lamps are connected in series, then the same results as to the amount of light produced will be obtained, if the resistance of the lamp is *low* as compared with the internal resistance of the battery. I will say this, however, that by making use of modern lamps of low resistence normally intended for use in series, a battery can be readily arranged in such a manner that, while it will bring one of these lamps up to normal incandescence, the total light obtained from

five similar lamps connected either in series or in multiple arc to the same battery will not be equal to the light produced by the single lamp, and that a result can be obtained comparable to that shown by Fontaine's experiments.

506 x-Q. Do you not think that, long prior to 1879, a person familiar with the laws of electricity would have understood perfectly well that, given a good incandescent lamp, by proportionately increasing the electromotive force of the current as new lamps were added to the circuit, one could keep all the lamps at a constant illuminating power, and thus, with a constant amount of current, produce the same amount of light at each one of the several lamps that he would obtain with a lower electro-motive force if he were to put but a single lamp in circuit?

A. Yes. I believe that I have answered substantially that same question before. King, in his English patent of 1845, speaks of regulating the number of armatures of a magneto-electric machine or cells of a voltaic battery so that the current may have an electro-motive force (intensity) corresponding to the number of lamps in circuit; and Lontin, about 1877, I think, operated his arc lights in series, and had his electric machine so constructed that the electro-motive force could be made proportional to the number of lamps in circuit; and I believe that Fontaine recognized that this was also essential, for I find it stated on page 185 of Higgs' translation of his work on electric lighting, that "it has been proved beyond a doubt that several lamps can be kept in action by one magneto-electric machine."

507 x-Q. In your answer to 4 Q (p. 3561 of the printed record), you have made a quotation from Schwendler's paper of March, 1879, introducing stars at one point to indicate the omission of some matter. Please give the language of the paragraph thus omitted?

A. The paragraph referred to reads as follows: "When a number of lights are connected in series the "resistance of each must be diminished, and when a "number of lights are joined in parallel the resistance

"of each must be increased in proportion to their num-
"ber, so as to maintain the total external resistance
"constant."

508 x-Q. In answer to 140 x-Q., you undertake to state with apparent exactness the percentage of lamps in central-station lighting which are replaced before breakage—on account of loss of efficiency, arising from increase in the resistance of the burner and from the blackening of the globe. Where did you get your information upon this point?

A. From a gentleman who has been for a number of years either manager or superintendent of one of the Edison central stations in New York.

509 x-Q. He, I presume, professed to speak from exact knowledge?

A. I so understood it.

510 x-Q. How exact is your information as to the number of lamps in isolated plants that are replaced before breakage?

A. I have no exact information concerning the practice followed in all insolated plants, but my impression is that the lamps are not generally replaced until they break. This, I understand, is the case in isolated plants of which I have particular knowledge.

Adjourned for lunch.

Resumed.

511 x-Q. What plants do you refer to as coming within your own knowledge?

A. I understand that in the Equitable Building, at 120 Broadway, Aldrich Court at 45 Broadway, the building at 44-46 Broadway, and the Gallatin Bank Building at 36 Wall street, all in the City of New York, this practice is followed.

512 x-Q. Take the single case of the Equitable Building, how do you know that they never replace lamps there till breakage occurs?

A. Only upon information.

513 x-Q. What kind of information?

A. From an engineer in the dynamo room.

514 x-Q. You never inquired then of the manager or superintendent of the building?

A. Not in that particular instance.

515 x-Q. When did you make the inquiry of the engineer?

A. To-day.

516 x-Q. Was it to-day that you got your information in respect to the other buildings you have named?

A. Yes.

517 x-Q. What knowledge had you in relation to this matter, to wit, the percentage of lamps in isolated plants that are replaced before breakage, at the time you answered 140 x-Q.?

A. I knew at the time that I left the employ of the Edison Company, in 1884, that as far as the isolated plants of that company were concerned, the lamps were not replaced until broken, and understood that this practice was still followed when I answered 140 x-Q. At that time I had positive information concerning the practice followed at the Aldrich Court Building which strengthened me in my general understanding of the matter.

518 x-Q. Referring to the blackening of the globe of commercial incandescent lamps, you have said (in answer to 141 x-Q.) that it is caused by "a deposit of carbon or some compounds of carbon and other substances coming from the burner." What is it that causes the carbon of the burner to be deposited upon the globe in the commercial lamps?

A. I do not know what all the causes may be, but experiments show that when the burner is heated to incandescence the particles of carbon are carried from it in practically straight lines and are deposited upon the interior of the lamp.

519 x-Q. What is the explanation of the particles of carbon proceeding from the burner to the globe in *straight lines?*

A. I do not know what the real reason for this may be.

520 x-Q. What is the supposed reason of this, as it lies in your own mind?

A. That they tend to go in straight lines, and the high vacuum permits it.

521 x-Q. Whence this tendency to go in straight lines?

Objected to as immaterial and irrelevant.

A. I do not know.

522 x-Q. Have you any theory about it?

Same objection.

A. No.

523 x-Q. Haven't you said in conversation, since this examination began, that it was probably due to the repellent action of the electric current?

Same objection.

A. I do not remember having made any such positive statement.

524 x-Q. Not that it was *probably* due to this cause?

Same objection.

A. I have no recollection of it.

525 x-Q. Haven't you in conversation with the defendant's counsel since this examination began, suggested any explanation of the observed fact that the particles of carbon, which in use are found upon the interior wall of the globe of an incandescent lamp, are carried from the burner to the globe in *straight lines?*

Same objection.

A. I do not remember making any such explanation. I have a faint recollection of some conversation in regard to the deposit upon the globe and the fact of there being no deposit opposite one side of the carbon loop, indicating that the particles move in straight lines.

526 x-Q. Do you suppose that this movement of the carbon particles in straight lines is the result of "air washing?"

Same objection.

A. Whether "air washing" has a part to play in causing the carbon particles to move in straight lines or not I do not know.

527 x-Q. You understand my question to relate to modern incandescent lamps, did you not?

A. Yes.

528 x-Q. What do you understand "air washing" to mean, as applied to modern incandescent lamps?

A. The mechanical action of the gas in the lamp chamber moving over the surface of the burner and tending to wear it away.

Adjourned until October 14, 1890, at 11 A. M.

OCTOBER 14th, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS CHARLES L. CLARKE CONTINUED:

529 x-Q. In your answer to 14 Q. you have criticized Wild's description of the physical properties of carbon as not contributing anything of value to the art of incandescent electric lighting. What physical properties does carbon possess, not named by Wild, which adapt it for use in incandescent lamps?

A. At the moment, I note that Wild failed to make mention of flexibility and elasticity; as I understand it, the burner of Lodyguine's lamp was rigid; he furthermore stated that the "sole inconvenience" of using carbon is due to the danger of combustion by the oxygen of the air, a statement which was entirely erroneous; the carbon burner of the very lamp of which Wild was speaking was enclosed in a globe filled with an inert gas in order to keep oxygen away from the burner, and did not have stability.

530 x-Q. Some reference has been made in your testimony to the Torricellian method of producing a vacuum *as practiced at the present day.* Wherein does this differ from the Torricellian method as *originally* practiced?

A. I do not know whether there is any difference or not. I believe, however, that the method pursued to-day is substantially the same as that made use of for many years, at least before the electric light was known.

531 x-Q. I find on page 74 of Gordon's Book on Electric Lighting (published by Appleton in 1884) the following statement:

"Efficiency and Durability.

"In comparing the amount of light per horse-power given by different incandescent lamps we must remember that we can increase it up to almost any amount we please by working the lamp at a higher temperature, only by so doing we reduce the life of the lamp from six months to perhaps three months, or a few weeks, days, hours or minutes. Only experience can show us what is the most economical temperature to work at, having regard both to the cost and trouble of renewing the lamps, and to the cost of the electric current which works them. This, 'the temperature of maximum economy,' will vary with the price of coal, being highest in places where coal is dearest, and *vice versa.*"

Do you agree with Gordon in these statements?

A. The statement is correct as far as it goes, but wages, interest and depreciation upon the entire property and plant, and all other expenses chargeable to the

cost of producing the current should likewise be taken into account.

532 x-Q. In an article by Mr. Preece (published at page 15 of Volume XIV., of the year 1885), of the *London Electrician*, I find it laid down that the light emitted by an incandescent or glow lamp varies as the sixth power of the current. Do you regard that statement of Preece as substantially correct?

A. I do not know, because I have not the data at hand to verify the correctness of Mr. Preece's conclusions; the article referred to in the *London Electrician* contains only the conclusions arrived at by Mr. Preece, as a result of experiments the details of which are omitted; from Mr. Preece's reputation as an electrician, however, and from what I know generally concerning this subject, I feel confident that the results which he obtained in these particular tests are correct.

533 x-Q. You have assumed throughout your deposition that the presence in the lamp globe of other gases than oxygen is fatal to such durability of a carbon burner as is essential to practical durability of the lamp. What are the facts upon which you base this assumption?

A. The assumption is based upon the literature of the art relating to lamps having carbon burners surrounded by an inert gas, which is referred to in my answer to 13 Q., as contrasted with the fact that modern lamps, in which the burners are contained in a high vacuum, are durable.

534 x-Q. Do the quotations made by you in your answer to 13 Q. warrant the conclusion that the presence in the lamp globe of the so-called inert gases is fatal to the practical durability of the carbon burner?

A. Not at all, when taken by themselves; for as a matter of fact, no one, I believe, knew that the inert gases were injurious, but, on the contrary, it was understood that their presence was beneficial because they kept the oxygen away from the burner. Moreover, inventors for several years prior to the patent in suit in directing their efforts toward making a durable lamp, made use of chambers filled with inert gas. Not until the discovery was made that carbon would be stable in a high vacuum did it become known that the presence of the inert gas was detrimental. Taken in connection with the knowledge of this discovery, I think that the quotations referred to warrant the conclusion stated in the question.

Adjourned for lunch.

Resumed.

535 x-Q. Aside from the quotations made by you in your answer to 13 Q., what authorities or facts have at your command which sustain your assumption, that the presence of the inert gases in the lamp globe are fatal to practical durability in a carbon burner?

A. I do not recall any others at the moment.

536 x-Q. How do you know that in the Sawyer & Man lamps, the disintegration of the carbon was due to the action of the inert gases, and not to the presence of the oxygen left in the globe when the lamp was completed, or subsequently leaking in through the imperfect joint?

> Objected to as an incorrect statement of the witness' testimony, and counsel for the defendant is asked to point out the parts of the witness' deposition which he thinks express this opinion.

A. I do not remember having made any statement to this effect. I think that the destruction of the carbon would be brought about both by the action of the inert gas and by combustion with oxygen.

537 x-Q. The inert gas, I suppose, operating by "air washing?"

A. I understand that the inert gas operates in this way; but whether this is its only action in bringing about the destruction of the carbon, I do not know.

538 x-Q. Is it not your understanding that, prior to the date at which Mr. Edison began working upon incandescent lamps, the effect of different degrees of heat upon the conductivity of carbon had been observed and carefully studied by the scientific men?

A. I believe that tests had been made within quite limited ranges of temperatures, but, so far as I know, not at temperatures which would enable one to determine the conductivity of carbon when incandescent.

539 x-Q. By your answer to 476 x-Q. you assume that, prior to the date of the patent in suit, there was known to the art a method adapted for the making of small carbon burners of high resistance—so small and of such high resistance as to adapt them for use in multiple arc. What prior process had you in mind in making that answer?

A. I had in mind Gaudoin's process of reducing suitably selected wood to the definite form which the carbon was to have, and its subsequent carbonization.

540 x-Q. Being the process as described in the third chapter of Fontaine's book on "Electric Lighting," first edition?

A. Yes.

541 x-Q. Do you also regard Carré's earlier method of making carbons as one adapted for producing carbons of such size and resistance as to be suitable for use in multiple arc?

A. I doubt whether this process could be practically utilized in producing such carbons. Inasmuch as they would have to be very small in diameter and relatively long, it would, I think, be exceedingly difficult to make such carbons from the mixture used by Carré—forced through a draw-plate and subsequently corbonized—which would be sufficiently homogeneous and uniform in size. Moreover, it would be difficult to put such fragile carbons through the several subsequent processes of impregnation with syrup and recarbonization which Carré deems essential.

Adjourned until October 15, 1890, at 11 A. M.

October 15, 1890.

Met pursuant to adjournment.
Present--Counsel as before.

Cross-examination of the witness, Charles L. Clarke, continued:

542 x-Q. You have referred quite frequently to certain editorials in *The Engineer*, and to others in *Engineering*. Have you any means of knowing what particular person wrote those articles?

A. I believe that Mr. Conrad W. Cooke, wrote the articles upon electric lighting which appeared in *Engineering*, although I cannot state definitely where I got that impression. I notice, however, that in his testimony given before the Parliamentary Committee on Lighting by Electricity, Mr. Cooke states that he had been a contributor to the literature of the subject, and wrote the articles which appeared in "Engineering," with one or two exceptions. I do not recollect the name of the author of the articles which appeared in *The Engineer*, although I have a recollection of having known it at one time.

543 x-Q. You have quoted from Dr. Morton's Government Report which is an appendix to the Government Lighthouse Board Report for 1879. What does that report show to be the average candle-power obtained in the various arc lights which were tested by the committee for each horse-power of energy expended on running the lamps?

A. I find, from Table 27, which is to be found on page 50 of this report, that the average light per horse-power of energy obtained as the result of eleven tests was equal to 1,211 candles. As I understand it, however, this does not show the average illuminating power in all directions, but is the result which was obtained by measuring the intensity of the light emitted in a horizontal direction only, which is much greater than the average; in fact, about twice as great.

544 x-Q. In your answer to 13 Q., you have made certain quotations from a lecture by J. W. Swan, before the Philosophical Society of Newcastle in the year 1880. Does not the context show that in the extracts which you made Swan was speaking of a date prior to October, 1877; and does he not proceed to set forth that in October, 1877, he set on foot experiments in incandescent lighting which resolved the difficulties spoken of in the extracts as previously existing?

A. According to the statements which were made by Mr. Swan himself in this lecture, which was delivered October 20, 1880, it would appear that in October, 1877, he endeavored to determine the effect of a high vacuum upon the volatilization of carbon. He omits, however, to state what results were obtained at that time, but says, without naming any date:

> "It was found, after many troublesome experiments, that *when the vacuum within the lamp globe was good, and the contact between the carbon and the conductor which supported it was sufficient, there was no blackening of the globes, and no appreciable wasting away of the carbons.* Thus was swept away a pernicious error, which, like a misleading finger-post proclaiming 'No road this way,' tended to bar progress along a good thoroughfare."

Whatever results may have been at first obtained by Mr. Swan, they were apparently not very flattering, for he goes on to state that:

> "It only remained to perfect the details of the lamp, to find the best material from which to form the carbon, and to fix this material in the lamp in the best manner. These points, I think, I have *now* (italics mine) satisfactorily settled; and you see the result in the lamp before me on the table."

This was nine months after the publication of the patent in suit.

545 x-Q. I asked you whether the quotations from Mr. Swan's lecture which you made on your direct

examination did not relate to a period prior to October, 1877. Please answer that?

A. Yes; but he does not name the date at which he resolved these difficulties, as alleged.

546 x-Q. That the Court may understand the real value of the quotations which you have made from Swan's lecture, I will ask you to quote all that he says on the subject of incandescent lighting?

Objected to as immaterial, irrelevant and incompetent.

A. The following are the parts of the Swan lecture to which, as I understand it, the question relates:

"I said that there is *another way* of producing electric light, namely, by *incandescence*. Lighting by incandescence is a branch of the subject which has a special charm for me, because I have bestowed upon it much thought and labor; and it is, I believe, *the* branch which will yield the largest crop of fruit. Electric lighting by incandescence is just as simple as arc lighting is difficult; all that is required is a material which is not a very good conductor of electricity, highly infusible, and which can be formed into a wire or lamina, and is either non-combustible in air, or, if combustible, does not undergo change in a vacuum. There are, so far as I know, just two substances that possess, in any sufficient degree for the purpose in question, the qualities I have specified. The two substances are—platinum, or an alloy of platinum with iridium, and carbon. Platinum has the advantage over carbon, that it is not combustible in air; it does not, like carbon, burn away if you make it white hot; but it is very inferior to carbon in the degree of heat it will bear without fusion; and for producing light by incandescence it is essential to economy that the incandescent material should be capable of enduring an extremely high temperature, because the amount of light emitted by an

"incandescent substance increases in a more rapid ratio than the temperature. When, for example, you have a piece of platinum wire or carbon red hot, it emits almost no light; but double its temperature by sending a double quantity of current through it, and it will yield much more than twice the light it did before. It is therefore evident that the hotter the incandescent material can be made, the less the light will cost per unit of power expended.

Iridio-platinum, comparatively with other metals, may be called extremely infusible, but compared with carbon it is nowhere. Carbon has, in fact, resisted without fusion the very highest degree of heat brought to bear upon it; and what that degree of heat is I can hardly estimate, it is so enormous. But carbon has been found so difficult to deal with, on account of its ready combustibility (and some other troublesome properties which I will mention afterwards), that experimenters have bestowed much attention upon platinum and iridio-platinum as the incandescent material for electric lamps.

Mr. Edison was, I think, the last who attempted to utilize platinum in an electric lamp; and there can be no doubt that he obtained better results with platinum, and came nearer making a useful platinum lamp than any experimenter in the same track who had gone before him.

Here is a view of Edison's platinum lamp. This is the lamp of which so much was promised and expected in October, 1878, and which led, you remember, to the panic in gas shares. This lamp did not realize the hopes of the inventor.

(I will not rekindle Mr. Crompton's Electric Sun, because I hope presently to show you some small lamps, whose light would be absolutely drowned in that fierce radiance as stars are by the light of day.)

Whilst Mr. Edison was endeavoring to produce a useful incandescent lamp by means of platinum, I was endeavoring to obtain the same end by means "of carbon. It had appeared to me for many years that if ever electric light was to become generally useful, it would, most probably, be by means of the incandescence of carbon. I had, long before the time to which I am referring, attempted to render this idea practicable. As a matter of history, I will briefly describe an experiment which I tried about twenty years ago. I had a number of pieces of paper and card of various forms and sizes buried in charcoal in a crucible. This crucible I sent to be heated white-hot in one of the pottery kilns belonging to Mr. Wallace, of Forth Banks. From the pieces of carbonized card which I thus obtained I selected a long spiral. The ends of this I clipped between small blocks of carbon carried by uprights, and connected with conducting wires. A small glass shade was cemented over this mounted carbon spiral, and the air was exhausted by means of a very good air-pump, lent to me for the purpose of this experiment by the Rev. Robert Green, of Longhorsley. A good vacuum (according to the ideas that then prevailed) having been produced, I applied the wires of my battery (consisting of ten cells of Callan's modification of Grove's battery) with great expectation of a brilliant result; instead of this, there was the most absolute negative presented to me; not a vestige of heat or light appeared in my long ringlet of carbonized paper. It was evident, and I immediately recognized the fact, that the electric current of the strength I was using would not go in sufficient quantity through so long a piece of carbon as I had taken. I therefore repeated the experiment with shorter carbon and a greater number of cells, and I obtained, under these altered circumstances, an extremely interesting result.

My carbon was in the form of an arch (this diagram will help my explanation), about one inch in height and width, and the strip forming the arch a quarter of an inch broad. The ends of the

"arch were held in small clamps, with square blocks of carbon.

The air-pump having been worked, I had the pleasure of seeing that when contact with the battery of forty or fifty cells was completed, my carbonized paper arch became red-hot, and it was evident that nothing more was wanted than a still stronger current to make it give out a brilliant light; but I had used up all the battery power at my disposal, and having reached this limit, I contended myself with watching the behavior of the arch, the engrossing question being—how long will it endure? I noticed that the inner part of the arch was hotter than the outer part, and that, perhaps in consequence of this, the arch became bent on one side. This bending gradually increased, until at last the arch had so far curled down that the top was on a level with the clamps, and on coming in contact with the sole of the lamp it broke in two, and the experiment collapsed.

That I confidently believe was the very first instance in which carbonized paper was ever used in the construction of an incandescent carbon lamp. I am now speaking of twenty years ago, and at that time the voltaic battery was the cheapest source of electricity known, and the means of producing high vacua were very much less perfect than they are now.

I laid my electric light experiments aside until about three years ago, when two things concurred to lead me to pursue the subject afresh. The discovery of the dynamo-electric machine had entirely altered the position of the question of electric lighting, shifting it out of the region of things scientifically interesting into that of things practically useful. The Sprengel air-pump, too, had been invented, and with its invention we had been provided with a means of producing much higher vacua than could be produced by the old form of air-pump. Mr. Crookes' radiometer experiments "had shown us what a really high vacuum was, and how to produce it. Mr. Stearn, of Birkenhead, an ardent scientific amateur, was so attracted by the extraordinary results Mr. Crookes had obtained by means of high vacua, as to go with great enthusiasm into the same line of experiment, and he soon acquired such a knowledge of the Sprengel pump, and such expertness in its manipulation, as perhaps was only equalled by Mr. Crookes himself. I had the good fortune to make Mr. Stearn's acquaintance, and that was the other one of the determining causes of my second attempt to solve the problem of electric lighting by the incandescence of carbon.

In the interval between the first and second periods I have mentioned, many attempts had been made by various experiments to render practicable incandescent carbon lamps, but none were entirely successful. Here is represented a variety of the most notable of these attempts. Some are vacuum lamps and some have air admitted. Sawyer & Mann's lamp is filled with nitrogen. When the incandescent carbon is in air it burns away, and must consequently be renewed just as a candle must be renewed; it must also be thicker than would be necessary in a vacuum, and being thicker, it requires a proportionally greater current to render it incandescent; both these circumstances are obviously against economy. The André lamp is one of the best of this type. In this the supply of air is limited; still this lamp and all those lamps are lacking in simplicity and in economy.

In all the various attempts to utilize the principle of the incandescence of carbon in vacuo, two great difficulties had stood in the way and baffled every attempt to overcome them. One was *the rapid wearing away, and consequent breaking of, the incandescent carbon*; and the other *the obscuration of the lamp by a kind of black smoke.* So uniformly did these phenomena present themselves that the

"idea was propounded, and generally accepted, that the blackening of the lamp globes was due to volatilization of the carbon under the action of the enormous heat to which it was subjected.

In Fontaine's work on electric light this passage occurs at page 180: 'Attentive examination of incandescent carbons through a strongly colored glass, has shown that they are not uniformly brilliant. They present obscure spots, indicative of non-homogeneity, and the position of cracks, which rapidly disintegrate the carbon. The vacuum never being perfect in the receivers, the first carbon is in greater part consumed. It would appear that, consequently upon the little oxygen contained in the lamp being transformed into carbonic acid and carbonic oxide, the carbon should be preserved indefinitely; but there is *then* produced a kind of *evaporation* which continues to slowly destroy the incandescent rods. This evaporation is, besides, *clearly proved by a pulverulent deposit of sublimed carbon, that we have found on the interior surface of the bells on the several interior parts, rods, contacts, hammer, etc.*'

If this idea of the volatilization of carbon were founded in fact, any further attempt to render incandescent carbon lamps *durable* by means of a vacuum would be *mere waste of time*; and durable they *must* be to be of any practical value.

Fortunately, I did not accept as conclusive the experiments which seemed to show that carbon was volatile, and that the blackening of globes of incandescent carbon lamps was an inevitable result of the carbon being very highly heated. I knew that the conditions under which, without exception, all previous experiments had been tried were such as did not allow to be formed anything approaching a perfect vacuum within the lamp. Screw fittings had invariably been employed to close the mouth of the lamp and the ordinary air-pump to exhaust the air. Under such circumstances it was certain that a considerable residuum of air would be con-

"tained within it, and also that it would leak. Then, there had never been any thought given to the gas occluded in the carbon itself, and which, when the carbon became hot by the passage of the current through it, would be evolved; nor had sufficient care been taken *to make the resistance, at the points of fixture of the carbon, less than in the carbon to be heated to incandescence.* It was evident to me that before any definite conclusion could be arrived at on the question of the volatility of carbon, the cause of the blackening of the globes, and the wearing away of the incandescent rods, *we must first try the experiment of heating the carbon to a state of extreme incandescence in a thoroughly good vacuum* (such as Mr. Crooks had taught us how to procure), *and under more favorable conditions, as to the contact between the incandescent carbon and the conductors supporting it, than had hitherto obtained.*

Accordingly, in October, 1877, I sent to Mr. Stearn a number of carbons, made from carbonized cardboard, with the request that he would get them mounted for me in glass globes by a glass-blower, and then exhaust the air as completely as possible. This delicate operation Mr. Stearn very kindly undertook, and very skillfully carried out. In order to produce a good vacuum, it was found necessary to heat the carbon to a very high degree by means of the electric current *during the process of exhaustion*, so as to expel the gas occluded by the carbon in its cold state; for otherwise, however good the vacuum was before the carbon was heated, immediately the current passed and made it white-hot, the vacuum was destroyed by the out rush of the gas pent up in the carbon in its cold state. In order to make a good contact between the carbon and the clips supporting it, the ends of the carbon were thickened, and, in some of the early experiments, electrotyping and hard soldering of the ends of the carbon to platinum was resorted to.

I will not weary you, however, with details, but simply say that the prescribed conditions

"having been rigorously complied with, it was found, after many troublesome experiments, that *when the vacuum within the lamp globe was good, and the contact between the carbon and the conductor which supported it sufficient, there was no blackening of the globes, and no appreciable wasting away of the carbons.* Thus was swept away a pernicious error, which, like a misleading finger-post proclaiming 'No road this way,' tended to bar progress along a good thoroughfare.

It only remained, to perfect the details of the lamp, to find the best material from which to form the carbon, and to fix this material in the lamp in the best manner. These points, I think, I have now satisfactorily settled; and you see the result in the lamp before me on the table. It is a very modest-looking affair, but its performance goes beyond its appearance. The carbon is extremely thin—a mere hair, and how wonderfully strong and elastic it is I will endeavor to show you by by means of the lantern. This carbon, unlike the carbon spoken of by Fontaine in the extract I read to you, is quite homogeneous and almost flinty in hardness, and it becomes harder by use in the lamp; the longer and the hotter it is heated, the harder it becomes. What degree of hardness it will ultimately arrive at, is an interesting question.

Here is a magnified view of the carbon ring in a state of incandescence. Observe how absolutely uniform in brightness it is; that proves it to be homogeneous and foretells its durability.

Now I will show you how easily lamps of this kind are lighted, and how completely this form of electric light can be divided and distributed.

Is it not a pleasant light? It is not so white as the arc light, but yet a whiter light than gas. Colors are correctly seen by it, as this picture shows. But the great merit of this light consists in its not being in contact with air, and therefore there cannot possibly be the slightest air-

"pollution caused by it. The rooms in which this light is used will be as pure by night as by day.

It is essential to economy in lighting by incandescence that the incandescent carbon should be very thin. The carbon I use is not one-twentieth the substance of the thinnest of the carbons formerly employed; and therefore one-twentieth of the current, costing one-twentieth the price, will produce in my thin carbon the same degree of luminosity as twenty times more current will produce in such carbons as were used in those ancient lamps. You will notice that in my lamp leakage is very thoroughly guarded against; the wire which passes through the glass not only having the glass fused around it where the wire and globe meet—but, in addition to this, the wire is coated with glass almost up to the carbon. In this way the vacuum is preserved very effectually.

You have, of course, all heard that, after Mr. Edison abandoned his platinum lamp as impracticable, he invented a new lamp in which carbonized cardboard is used. Here is a diagram of Mr. Edison's carbon lamp, with its horseshoe of carbonized paper. It is in some respects like mine, but latterly I have given up the use of carbonized cardboard, and am now using a material as much better than carbonized cardboard as carbonized cardboard was better than the material previously used. In an article which appeared in the February number of "Scribner's Magazine," authenticated by a letter from Mr. Edison in the same publication, it is stated that Mr. Edison was the first to use carbonized paper; that, however, is incorrect. And this also occurs after a description of the Sprengel pump used in exhausting these lamps: 'Mr. Edison's use of carbon in such a vacuum is entirely new.' Now, I dare say there are many here who will remember this little lamp which I showed here two years ago in action. This lamp has exactly the same simplicity as my present lamp, being composed entirely of three substances,

"namely, glass, platinum and carbon; and it was exhausted in precisely the same manner, and to the same degree, as that which Mr. Upton—no doubt in good faith, but still in error—speaks of as '*entirely new.*'

I do not mention these things in any way to disparage Mr. Edison, for no one can esteem more highly his inventive genius than I do. I merely state these facts because I think it is right to do so in my own interest and in the interest of true history.

The complete seclusion of the light in this lamp from contact with air suggests its adaptability to coal-mine illumination. There are many and great difficulties in the way of such a use of the lamp, but the question is at least worth consideration. But the great purpose to which a lamp of this kind is applicable is the lighting of your houses. In view of such an application, two all-important questions present themselves: one, as to distribution, another as to cost. Can this light be divided, distributed and measured as gas is divided, distributed and measured? And at what cost? It is quite impossible in a brief lecture to discuss these questions exhaustively, but, as far as possible, in a few words I will answer them.

First, then, as to division and distribution. It has been asserted, on very high authority, that great loss necessarily attends the division of the electric light. To a certain extent this is true of lighting by the electric arc, but it is totally and absolutely erroneous of lighting by incandescence. *There is, practically, no loss in dividing the electric light produced by this means.* Faraday has stated the law of the case somewhat in these words: 'An electric current which will heat one inch of wire *white-hot*, will also heat to the same temperature 100 inches, or an infinite length of the same wire.' There is no question of the truth of this. Now, as it is only necessary, in order to maintain a given current, to increase the force which produces it in "the same proportion as you increase the resistance to its flow, it follows that the cost of raising to a certain degree of incandescence a longer or shorter length of carbon, or of maintaining a 10-candle light or 100-candle light, will be exactly proportional to the light produced. If you have an electro-motive force sufficient to drive such a current through 100 inches of my carbon filament as will render it incandescent, you may either have the 100 inches in one continuous length all in one lamp, or you may cut up the 100 inches into 100 pieces and place each piece in a separate lamp, and the 100 lamps in 100 different places, without any difference in the aggregate amount of light from the one undivided light and from the 100 separate lights. You may even contemplate on this principle the economical production of an electric light as small as a rush-light.

With regard to distribution, I believe that it will prove to be practicable to light any large town—all Newcastle, for instance—by means of wires laid in the ground as gas pipes are laid, and all branching from one centre, and conveying the electric current to lamps like this. The lamps now lighted are supplied by the current coming from generators working at the far end of Mosley street (a quarter of a mile away); and it would be just as easy by using a more energetic current—a current as it were under higher pressure—to maintain these several miles away; and for this purpose the conductors need not be large—not so large, certainly, as to make the distribution of electric current more costly than the distribution of gas.

For supplying large towns with electric lights, Mr. Edison proposes to have a number of centres for the supply of electric power, perhaps a quarter of a mile apart, whence wires would be sent out in every different direction, distributing the current to the houses round about. His plan of distribution is this: He proposes to send out bundles of

"main wires from each of the centres of supply, and from these main wires to branch as many small wires into the houses as there are lamps to be lighted, each branch wire proceeding from a main wire to the place where the lamp is situated, and from thence to a return main wire. Now, although this plan has the great merit of simplicity, I do not think it will answer, except for very short distances. When a number of lamps are grouped together in that manner, it is necessary that the individual lamps should offer a very high resistance to the current, for if each lamp does not offer an extremely high resistance to the passage of the current there must be great waste, a large proportion of energy being in that case spent in heating the conducting wires, instead of the carbon in the lamps. Mr. Edison accordingly proposes to make his lamps of a very high resistance; he proposes to use for the incandescent material a form of carbon which offers a higher resistance then simple carbon in its compact state; but if carbon pure and simple is used, then I submit it had better be in as stable and condensed a state as possible, because in process of use it tends to consolidate, and it is undersirable that any change should take place in the lamp during use. A filament of carbon in its best state for incandescent lamps, as thin as it is safe to use in a lamp, and of a length sufficient to give a light equal, say, to one burner, or ten standard candles (a unit of light which I think we must not go beyond in planning an extensive system of town lighting) will not offer so high a resistance as that which Mr. Edison has made the basis of his scheme of distribution. With lamps of this resistance the result would be that before many were bridged across from one main wire to another, as much or more work would be done in the conducting wire as in the lamp. The only way of avoiding this waste of energy, without abandoning the idea of small units of light, would be either to employ enormously thick "conductors or have a very limited area supplied from one source. I think the difficulty is capable of being surmounted in this way: Instead of grouping the lamps as Mr. Edison proposes, each lamp being as it were a loop or bridge between two mains, I propose to string them in series, 10, 50, or perhaps 100 lamps being all interposed in one and the same line. In this way every lamp would *add* to the resistance of the line, instead of, as in Mr. Edison's plan, *diminishing* its resistance. The waste of energy in the conducting wire would thus be avoided. A copper wire, less than one-eighth of an inch thick, would supply current for one such series of, say, from ten to one hundred lamps, at five miles distance, with a very small percentage of loss; while to supply at the same distance a corresponding number of lamps on Mr. Edison's plan would demand copper conductors of such thickness as would certainly make the plan far too expensive; or, if such thick conductor was not used, there would be an impracticable, extravagant waste of energy in the wire. If even fifty per cent. of the energy were expended in the wire, the size of the conductor required to transmit the current, say, even two miles, would be far too great.

There is no way of escape that I know of from this dilemma, viz., that either we must make our unit of light larger than necessary for a very great many purposes, and so give up the idea of extensive division and extensive distribution, or, in order to gain these points, we must group the lamps in the manner I have proposed. There are, no doubt, difficulties in the carrying out of my plan, but none that are not easily surmountable. For example, if twenty, fifty or a hundred lights were in a series, a break in any part of the line would extinguish all the lights. This danger can be met in two ways: I would have only one lamp belonging to a given line in one house, so that the extinction of such a line of lights as we are con-

"templating would not be a very serious mishap; but I would make such a mishap extremely unlikely to occur, by placing along with each lamp an automatic circuit closer. This would so act as to bridge over the gap made by the accidental breaking or failure of a lamp, and so prevent the extinction of the rest of the lamps in the series, while a fresh lamp was put in the place of the broken one—a thing no more difficult, and probably not more costly, than the replacement of a broken gas burner chimney, or globe.

There is another difficulty, occasioned by the variation of the current in proportion to the number of lamps in action. What is required in this case is to maintain a uniform current in the line of lamps, whether one or a hundred are a-light. This can be accomplished by self-acting apparatus somewhat on the principle of the governor of the steam engine, and which would automatically raise or lower the *electro-motive force* by steps of 100ths, according to the number of lamps in use.

I have also considered the question of measuring the current, and, if time allowed, I could show you that that can be done as easily as the measuring of gas. Similarly, all other practical difficulties arising out of this method of distribution can be met, and being met, are at liberty to contemplate great central works, producing electricity by large steam engines, and distributing it by means of wires to a whole town, exactly as gas is now distributed by gas works.

I have already referred to the cost of electric light produced on the arc principle, and shown that when the circumstances are favorable to the employment of that method, it is much more economical than gas light. The economy of lighting by incandescence has not been exemplified by so many instances of actual practical use. One thing is, however, *quite clear*, and that is, that *electric lighting by incandescence is an economical pro-*

"*cess*—it will be less costly than gas lighting. That is conclusively demonstrated by the fact that 1,000 feet of gas employed in working a gas engine to develop an electric current, and used in my lamps, will yield more light than 1,000 feet of gas consumed in the ordinary way in gas burners. This room is now lighted by twenty of my electric lamps, and to produce the current which feeds them under 160 cubic feet of gas per hour is being burnt in a gas engine; before my lamps were kindled the room was lighted by 70 gas jets, consuming, I am told on good authority, about 200 feet per hour. It is very evident that we have got more light out of the gas through the medium of electricity than was got from the larger quantity of gas which those burners consumed. Our conditions here are somewhat unfavorable to my light for a fair comparison, but from measurements carefully made, both of light produced and current required to produce it, I am warranted in saying that at least twice as much light will be produced by a certain quantity of gas used to generate an electric current employed in my lamps as would be obtained from the same quantity of gas burnt in gas burners in the usual manner. If that is so, then it is evident that when, instead of the motive power of gas, that of steam, produced in the most economical manner, is employed, this method of electric lighting will be very much less costly than gas lighting. I reckon that 40 pounds of coal employed in raising steam to generate electricity is capable of producing in my lamps the effect of 1,000 feet of gas burnt in gas burners in the ordinary manner. The economical view of the question is therefore, in my opinion, very favorable to electric lighting, and I think fully warrants me in anticipating an extensive substitution of electric light for gas light.

The great difficulty which till now has completely blocked the way to any general use of electric light was *the difficulty of division. That difficulty is now*

"*completely overcome* by the method of producing electric light by the incandescence of carbon in vacuo, of which I have given you a practical demonstration to-night.

Eighty years ago Science gave us enlarged means of turning night into day; since then not a little of our lifetime has been spent in gas-lit rooms, and it has been somewhat of a reproach to Science that she has not provided us with this larger measure of light without at the same time imposing on us the necessity of breathing a vitiated atmosphere. To-day Science vindicates herself; henceforth we may make the long nights of our northern winters bright without any such sacrifice."

Defendant's counsel offers in evidence British Blue Book containing the British Provisional Specification of Sylvanus F. Van Choate, filed in the British Patent Office October 31, 1878, and numbered 4388, and the same is marked "Defendant's Exhibit, Van Choate Specification."

It is stipulated by complainant's counsel that this specification was officially printed and published on the 31st day of May, 1879, subject to correction of error in date if such be hereafter discovered.

It is hereby stipulated, subject to the correction of errors therein, if any such shall be hereafter found to exist, that the diagram marked "Pope's Diagram of the Franklin Institute Test of Incandescent Lamps" is a correct representation of the average changes in candle-power and resistance hot of the first ten lamps in the tables of Edison lamps, as given on pages 56-65 of the Report of the Committee, marked "Defendant's Exhibit Franklin Institute Report on Incandescent Lamps."

Defendant's counsel offers the said diagram and the said report in evidence, and the same are marked respectively "Defendant's Exhibit, Pope's Diagram of the Franklin Institute Test of

Incandescent Lamps," and "Defendant's Exhibit Franklin Institute Report on Incandescent Lamps."

CROSS-EXAMINATION CLOSED.

Adjourned until October 16, 1890, at 10 A. M.

OCTOBER 16, 1890.

Adjourned to October 17th, at 10 A. M.

OCTOBER 17, 1890.

Met pursuant to adjournment.
Present—Counsel as before.

RE-DIRECT EXAMINATION OF THE WITNESS, CHARLES L. CLARKE, BY MR. DYER:

547 Re-d. Q. In answer to 512, 513 and 514 x-Qs. you say that your information about the practice of not renewing lamps in the Equitable Building was obtained from an engineer in the dynamo room, and not from the superintendent. Have you since made similar enquiries of the superintendent, and, if so, with what result?

Objected to as calling for hearsay testimony.

A. I have since that time made the same inquiries of Mr. Wilson, who is the superintendent and chief engineer of the Equitable Building, and he informed me that the lamps are not taken from the circuit and discarded until broken.

548 Re-d. Q. In your cross-examination at several points, and especially in answer to 205 to 211, 405, 411, 423 and 424 x-Qs. and perhaps elsewhere, you

have expressed the opinion that practically durable incandescent electric lamps cannot be produced unless the carbon burners of such lamps are heated by the passage of an electric current there through, while the lamp globes are being exhausted, and that the temperature of the carbons during this heating should be higher than that at which the carbons will be heated in the use of the lamps. In answering 483 x-Q. you state that you do not *now* understand that it is necessary to heat the burners during exhaustion to a higher temperature than that at which the burners would subsequently be heated in the use of the lamps. What do you now understand the fact to be with respect to the necessity of electrically heating the carbon burners during exhaustion in order to produce practically durable lamps?

A. In answering the questions first mentioned I was convinced that electrical heating was necessary in order to obtain a lamp which would be of any practical use, for the reason that the importance of the process had been set out prior to the date of the patent in suit, and has, so far as I know, been universally employed in the manufacture of incandescent lamps since that date. Before answering 483 x-Q., however, I came in possession of facts which convince me that I was in error as to the absolute necessity of electrical heating in order to obtain a lamp which would have been durable enough for practical purposes at the date of the patent, and that, on the contrary, electrical heating would not have been necessary with a lamp like that described in the patent in suit, having a carbon burner of small mass, and not having large metallic parts inclosed in the glass chamber, although good skill and judgment would, in view of the prior state of the art and the instructions contained in the patent, have suggested the use of this method in order to obtain the best possible lamp. The facts that I refer to are that Mr. Edison made tests in 1884 in relation to this matter, and that the ordinary 16-candle-power lamps, when exhausted without electrically heating the burner—the glass bulb being heated externally with a spirit lamp, which is the method pursued in driving air from the surface of the glass, as practised for many years in the manufacture of vacuum tubes—were found to have a life of nearly five hundred hours when run under normal conditions. Before I had obtained this information tests were begun at my request at Mr. Edison's laboratory upon lamps exhausted in the manner above mentioned, and although for want of time they have at date been run but 112 hours, their condition at the present time promises a useful life.

549 Re-d. Q. In your cross-examination at several points, and especially in answer to 56 to 94 x-Qs. and to 217, 328 and 362 x-Qs., and perhaps elsewhere, you seem to have expressed the opinion, in substance, that while the solution of the problem of the subdivision of the electric light was in fact accomplished by the lamp described in the patent in suit, having a filamentary carbon burner and adapted to give the light of a gas jet and to be operated in multiple arc, yet that, had there been in existence prior to the patent in suit a durable lamp having a carbon *rod burner* and giving many times the light of a gas jet, provided its carbon burner had been made by a method which could be successfully used to produce filamentary burners, the lamps of the character just described would have been produced, and the problem would have been solved by the employment of the then existing knowledge and without the exercise of invention. Do you desire to modify or change this opinion?

A. After a careful consideration of the present question and of the circumstances under which I was led to express the opinion referred to, I feel that the position taken by me was not a proper one, and I desire to modify it. The assumption upon which it was founded, namely, that the durability of carbon burners was first ascertained for those of large size and high illuminating power, was, as I have often stated, contrary to what the history of the development of the art shows to have been the fact, or to what I believe would have been possible, the discovery having been actually made with respect to very small burners of low illuminating power which directly solved the problem of subdivision. If the stability of carbon had been discovered for carbon rods, this would, I think, have been of itself a very great advance in the art of electric lighting; but whether the art, while deeming subdivision to be a very desirable result to accomplish, would have continued for a time to use the lamps having rod burners, entirely unappreciative of the adaptability of anything involved in their construction to the making of small lamps, and whether, in view of all the facts relating to the state of the art as it then might have existed under these circumstances, a person, in eventually making the small lamp, would have arrived at a practical result without making an invention, are matters which I do not feel competent to pass upon, because, as I now look at it, assuming that one important step in the actual history of the development of the art had been changed, I am not in a position to know how this might in other respects have turned it from the course which we know it did take, and possibly have changed the entire history of its development.

Complainant's counsel offers in evidence a blue-book copy of British Patents No. 2402, dated 17th June, 1879, and granted to Thomas A. Edison for improvements in electric lights and in apparatus for developing electric currents and regulating the action of the same, and the same is marked "Complainant's Exhibit Edison's British Platinum Lamp Patent."

The introduction of the foregoing exhibit is objected to by the defendant on the ground that, although the patent bears date of June 17, 1879, it was not in fact issued or published until a long time thereafter.

Re-cross-examination by General Duncan:

550 Re-x-Q. You refer in your re-direct to the renewal of the lamps in the Equitable Building. Do you know how many hours any of those lamps have been run?

A. No.

551 Re-x-Q. Do you know whether any of them have been run as long as three hundred hours?

A. I do not know for a fact whether any of them have been in use for that length of time or not?

552 Re-x-Q. Is it not a fact that in the offices of the Equitable Building the current is turned off from these lamps at six o'clock in the afternoon?

A. That I do not know.

553 Re-x-Q. Would you have any objection to asking Mr. Wilson about this and putting the result on the record?

A. Not the slightest, if it is desired.

554 Re-x-Q. You have referred, in answer to 548 Re-d. Q., to certain alleged experiments made by Mr. Edison in 1884, in which he is said to have made use of the external application of heat to the lamp bulb to aid in securing a vacuum. You do not understand, do you, that the Edison Company has ever adopted that process in the manufacture of their lamps?

A. I do not know whether the company ever has made a commercial use of exactly that process of applying the heat externally. At the present time, I believe, this process is not made use of.

555 Re-x-Q. Don't you believe the fact to be that in the manufacture of their commercial lamps the Edison Company has always made use of electrical heating of the burner while the lamp was on the pump?

A. I so understand it.

556 Re-x-Q. Did you take part in the alleged Edison experiments of 1884, referred to in your answer to 548 Re-d. Q.?

A. I did not.

557 Re-x-Q. Personally, then, you do not know the details of those experiments?

A. No.

558 Re-x-Q. Did you yourself make and exhaust the lamps which you say have lately been treated at the Edison laboratory, in which external heating was made use of?

A. I did not.

559 Re-x-Q. I suppose that you are aware of the fact

that the defendant claims to have made recently the discovery that some twenty years or more ago Dr. Isaac Adams made incandescent lamps, alleged to be practically durable, which were made by sealing up a thin strip of carbon (stated to be something like three-sixteenths of an inch in width, from 0.005 to 0.010 inch in thickness and an inch or thereabouts in length) in a highly exhausted all-glass chamber, with platinum leading-in wires, and that defendant has procured from the Court an order enlarging its time to take evidence in regard to such alleged manufacture of lamps by Dr. Adams?

A. I am aware of the facts stated in the question, excepting as to the dimensions of the burners—although I have understood that their size was something approximating the dimensions given.

560 Re-x-Q. How long have you known these facts?

A. Several days, possibly a week.

561 Re-x-Q. Would you regard the burner which I have described in the last question but one, as *a filament* of carbon, or would you classify it as a rod of carbon?

A. I think that it should properly be called a rod.

562 Re-x-Q. Why so?

A. I think that I can best answer that question by referring to the various parts of my former testimony, where the question of rods and filaments has been discussed, and in which I expressed the opinion that the largest burners made by the Thomson-Houston Electric Company for use in series are rods. The burner referred to in the present question, if its thickness be taken as 0.005 inch, has a cross-section, the area of which is considerably larger than that of the Thomson-Houston burners referred to, and nearly as large as the largest series burner made by this company.

Chas. L. Clarke.

Adjourned until October 18, 1890, at 11 A. M.

October 18, 1890.

Adjourned subject to notice.

NEW YORK, July 31, 1890.

Present—R. N. DYER for complainant and S. A. DUNCAN for defendant.

SHERBURNE B. EATON, a witness produced on behalf of complainant, being duly sworn, in answer to questions by Mr. Dyer, testified as follows:

1 Q. What is your name, age, residence and occupation?

A. Sherburne B. Eaton; age 50; residence, New York City; lawyer.

2 Q. Have you at any time been an officer of the Edison Electric Light Company, and if so, for what length of time?

A. I was vice-president and principal executive officer from January 11th, 1881, to October 25th, 1882, and was president from October 25th, 1882, to October 30th, 1884. Ever since that last date I have been the general counsel of the Company, and still am.

3 Q. Mr. George W. Hebard, the president of the defendant Company, has testified that the defendant Company was not notified that it was infringing the patent in suit, No. 223,898, prior to the bringing of the bill in this suit; Mr. Hebard, however, admits the receipt by the defendant Company, in June and November, 1882, of notices to desist infringing, to which were attached lists of patents, including the patent in suit. Do you agree with Mr. Hebard that the defendant was not notified of its infringement of the patent in suit?

A. I do not agree with Mr. Hebard in this matter. Besides the notices to which Mr. Hebard refers, the officers and agents of the defendant Company had frequent notice that the incandescent lamp made by the defendant Company was claimed by the Edison Company to be an infringement of the patents of the Edison Company, and especially of the patent in suit. During the years 1880 and 1881, while I was vice-president of the Edison Company, I had several interviews with Mr. Charles R. Flint, at that time president of the defendant Company, in which Mr. Flint pressed

upon my attention the advantages of a consolidation in some form of the interests of the complainant and defendant companies. In these conversations, the fact that the Edison Company claimed to possess by its patents, a monopoly of the business of making and selling incandescent lamps, was a prominent feature of discussion. The patent in suit, which was known as the "Filament Patent," was always considered by us as our most controlling and most important patent upon incandescent electric lamps; and this patent was frequently spoken of in these interviews in connection with the claim advanced by me that the lamps being made by the United States Electric Lighting Company infringed this patent as well as other patents owned by the Edison Company. At the time of the Electrical Exposition in Paris, in 1881, the Maxim incandescent lamp, which was being exhibited at Paris by the defendant Company or its representatives, was made the basis of a suit for infringement by the owners of the Edison Patent in France, corresponding to our Filament patent in this country, and the fact that the Maxim lamp made by the United States Company was claimed to be an infringement of the Filament patent, was made known by the bringing of the Paris suit, and through newspaper publications in reference to it, both in Europe and this country. I refer to an interview published in the "New York Tribune" for August 13, 1881, had with myself, and entitled "Enjoining the Maxim Lamp"; and also to an article published in the "New York World," August 21, 1881, entitled "The Maxim Light at Paris." In 1882 a suit was brought upon the English patent corresponding with our "Filament" patent in this country, against manufacturers of the Swan incandescent lamp in England. As further showing the publicity given to the claims of the Edison Company that all the incandescent lamps, including the Maxim lamp, infringed the Filament patent, I will refer to the publication in the "New York Times" for April 27, 1882, entitled "Electric Light Monopoly," also a publication in the "New York Commercial Advertiser" for August 8, 1882, entitled "An Electric Light War"; the patent referred to in this publication as No. 238,898, dated January 27, 1880, is the patent in suit, the number being printed incorrectly; to a publication in the same paper for August 10, 1882, entitled "The Electric Light War"; to a publication in the "Paterson Daily Press" of September 2, 1882, entitled "Electricity or Gas," and to a publication in the Davenport, Iowa, "Daily Gazette" of May 22, 1883, entitled "Edison's System."

4 Q. Why was not suit brought in this country against the defendant company by the Edison Company while you were vice-president and president of that company?

A. The reason is stated in my report to the stockholders of the Edison Company at the annual meeting held October 23, 1883, which report has been put in evidence by the defendant. It is there stated, "The bringing of suits against infringers of the Edison patents is a subject which has frequently occupied our attention during the year. * * * Formal notices of infringement, in order to fully preserve our legal rights, have been served upon the various electric light companies that are clearly and undoubtedly infringing, but no suits for infringement have thus far been begun, nobody, as yet, having injured us enough to make it worth our while to go to the trouble and great expense of suit." While a number of companies were engaged at that time in the business of electric lighting, they all, with the exception of the Edison Company, were making and selling arc light apparatus, the defendant company being also engaged to a limited extent in making and selling incandescent electric lamps. We contemplated bringing suit upon the "Filament" patent and other patents against the defendant company as early as 1880, and in 1881 we employed counsel for that purpose, and had investigations made by experts, who reported in favor of bringing the suit, but, on account of the great expense and the time that we considered it would be necessary to employ Mr. Edison, thus taking him away from his experimental work, upon which we depended largely

for the development of the business in new lines, we concluded to defer bringing suit, in view of the fact that the defendant company was doing little or no business, and was not seriously competing with us. In 1883, in order to ascertain whether the defendant company was competing to a serious extent, and with a view of bringing suit if we found that they were, we had an investigation made of all the incandescent electric light plants put out by the defendant company, and the conclusion we reached from this investigation was, that the competition by the defendant company had not reached that point where it would be worth while to bring suit. The fact that we had reached this conclusion was given more or less publicity through the public press, as well as through announcements issued by the Edison Company or its agents. I refer to the statement contained in the article taken from the "Paterson Daily Press" of September 2, 1882, before alluded to, in which I am quoted as saying: "When the Swan light, which the Brush Company is preparing to put upon the American market, is offered for sale, the Edison Company will begin suit for infringement; and also against the United States Electric Light Company, should the Maxim lamp interfere with the business of the Edison Company." I will also refer to the announcement issued by Spencer Borden, the New England agent of the Edison Company for Isolated Lighting, and dated Boston, November, 1883. This shows, in addition, that as a result of our investigation down to July, 1883, there were 30 incandescent electric light plants of the defendant company in operation at that time, and 394 plants of the complainant company.

5 Q. Did the Edison Company, while you were connected with it, as an officer, grant licenses under its patents relating to incandescent lighting, and especially the patent in suit, to other parties?

A. It did grant licenses to a number of local companies organized to introduce the Edison incandescent light in towns and cities. The Edison Electric Illuminating Company of New York, received such a license on March 23, 1881. Many licenses were granted within the following two or three years, and I find, by referring to a circular issued by the Edison Company, that in August, 1886, the company had in operation fifty-eight central station plants; these central station plants are operated by companies which receive licenses under the Edison patents, including the patent in suit, each for a limited territory.

6 Q. I call your attention to the bulletins of the Edison Electric Light Company, numbers 1 to 22 inclusive, portions of which have been put in evidence by the defendant; were these bulletins issued, as appears on their face, by the Edison Company, and on the dates given?

A. They were. These bulletins were originally issued for circulation among the agents of the company, but later on the circulation was extended so as to include stockholders and others, interested in the operations of the company.

7 Q. Are the statements contained in these bulletins regarding the progress of the business of incandescent electric lighting correct?

A. So far as I know they are substantially correct.

8 Q. I call your attention to a paper marked, "Extracts from Edison Bulletins." Are these extracts correct copies of the corresponding portions of the bulletins themselves?

A. They are.

9 Q. The defendant's counsel have offered in evidence a paper entitled, the "Swan Lamp Patents," forming a part of Bulletin Number 21, from what source did the statements contained in this paper emanate and how did it come to be published?

A. The paper referred to was a report prepared by Major Wilber, who was at that time the solicitor of patents for the Company, and the statements contained in it are expressions entirely of his own personal views. The Bulletin Number 21 is composed of several papers, each of considerable length, taken from different sources, and is different in this respect from the other bulletins published by me, which contain carefully edited matter usually reduced to short paragraphs, and

taken from various sources, such matter being of interest to the business.

Complainant's counsel offers in evidence typewritten copies of the following newspaper publications referred to by the witness in answer to question 3, and the same are marked as follows:

The interview with the witness, published in the "New York Tribune" for August 13, 1881, and the same is marked "Complainant's Exhibit Eaton Tribune Interview of August 13, 1881."

The interview with the witness published in the "New York World" for August 21, 1881, and the same is marked "Complainant's Exhibit Eaton World Interview of August 21, 1881."

The publication in the "New York Times" of April 27, 1882, and the same is marked "Complainant's Exhibit Times Article of April 27, 1882."

The publication in the "New York Commercial Advertiser" of August 8, 1882, and the same is marked "Complainant's Exhibit Commercial Advertiser Article of August 8, 1882."

The publication in the same paper for August 10, 1882, and the same is marked "Complainant's Exhibit Commercial Advertiser Article of August 10, 1882."

The publication in the "Paterson Daily Press" of September 2, 1882, and the same is marked "Complainant's Exhibit Paterson Press Article of September 2, 1882."

The publication in the "Davenport (Iowa) Daily Gazette" of May 22, 1883, and the same is marked "Complainant's Exhibit Davenport Gazette Article of May 22, 1883."

Defendant's counsel consents to the use in evidence of the typewritten copies of the publications just offered in evidence by complainant's counsel and admits, subject to correction of errors, that such typewritten copies are correct copies of the publications and that the publications were made in the newspapers stated and upon the dates given.

Defendant's counsel, however, objects to the introduction of each and all of the foregoing publications as immaterial and as inadmissible, being of the nature of hearsay testimony.

Complainant's counsel also offers in evidence a printed copy of the announcement issued by Spencer Borden, the New England agent of the Edison Company for Isolated Lighting, November, 1883, and the same is marked Complainant's Exhibit Borden Announcement of November, 1883.

Defendant's counsel objects to the introduction of this exhibit as immaterial and as being of the nature of hearsay testimony only, and because it does not appear that any publication of the document was ever made.

Complainant's counsel also offers in evidence the extracts from Edison Bulletins referred to in question 8 and the same is marked Complainant's Exhibit Extracts from Edison Bulletins.

It is stipulated that defendant may quote from the Edison Bulletins such further extracts as they may choose; notice of such extracts to be given before the closing of complainant's proofs herein.

CROSS-EXAMINATION OF S. B. EATON, ESQ., BY GEN. SAMUEL A. DUNCAN:

10 x-Q. You say in answer to question 3 that the so-called Filament patent was always considered "by us" (by which I suppose you mean the Edison Company) as your most controlling and most important patent upon incandescent electric lamps. Can you refer to any of the Bulletins or formal notices—such, for instance, as the printed circulars or advertisements—in which your company laid more stress or emphasis upon that patent than upon certain other patents mentioned in connection with that one?

A. The patent in suit was always spoken of by the officers of the company and by the agents of the company as the most important patent connected with the lamp. That fact was continually put forward in our dealings with the public and in our interviews with parties engaged in electrical affairs. I cannot now recall any printed publications wherein we gave a special prominence to this patent except those already introduced in evidence, such, for instance, as the Exhibit taken from the "Commercial Advertiser" of August 8, 1882, where this patent is particularly specified and its claims set forth.

11 x-Q. In this particular exhibit you are reported to have mentioned in connection with the patent in suit at least two others as being "fundamental," are you not?

A. Yes, sir.

12 x-Q. That exhibit is a mere newspaper article apparently, a small portion of which purports to be the substance of an interview with yourself?

A. But the claims are set forth with care and my recollection is that they were prepared under my direction.

13 x-Q. You at the time regarded those claims as a correct statement of what is found in the corresponding patents?

A. They were intended to be substantially so.

14 x-Q. And you intended that to go forth to the world as an official interpretation of the patents to which this statement related?

A. No, sir; in fact I am not certain that that is printed as it was doubtless given to the interviewer.

15 x-Q. Have you any doubt on that point?

A. I have no opinion one way or the other.

16 x-Q. Do you then adopt or do you repudiate the statements contained in this newspaper exhibit as emanating from you?

Question objected to as immaterial and incompetent, so far as the evidence may be used to put an interpretation upon the patent in suit.

A. I adopt them substantially as printed with reference to this patent.

17 x-Q. Which one of the four claims set forth in that newspaper article do you consider as relating to the patent in suit?

Same objection.

A. Neither one of the claims, as stated in the interview, corresponds with the claims of the patent in suit, but No. 3 of the newspaper statement resembles one of the claims of the patent in suit. No. 2 also bears a rather close resemblance to one of the claims in the patent in suit.

18 x-Q. Which claims of the patent do you consider are fairly embodied in the claims 2 and 3 of the newspaper statement?

A. No. 3 of the newspaper statement is an imperfect statement of the third claim of the patent. No. 2 of the newspaper statement is an imperfect statement of claim No. 2 of the patent.

19 x-Q. What do you mean by "imperfect statement?"

A. I mean that the whole subject matter of the claim as set forth in the patent is not set forth in the newspaper interview.

20 x-Q. At the time of that interview, did you understand that you were making an imperfect statement of the scope of your company's patents?

A. I do not remember.

21 x-Q. Do you find that the statement of the scope of these patents as contained in that newspaper interview is substantially the same as the statement of their scope found on page 60 of the Twenty-first Bulletin of your company?

A. It is.

22 x-Q. Can you tell to what patent claim No. 1 as contained in the newspaper interview related?

A. I recall no Edison patent which contains the words "without regard to its material, resistance or mode of preparation," but the general statement of claim No. 1 of the newspaper interview closely resembles claim No. 1 of Patent No. 227,229.

23 x-Q. It was intended, was it not, by that form of statement to represent to the world the interpretation which you at that time put upon that patent, No. 227,229?

A. My recollection is that these four statements of claims set forth in the newspaper interview were intended to be a fair statement of what, in our opinion, our patents covered, and my recollection is—although I cannot for the moment point to any reference to sustain my statement—that these claims were carefully prepared and were used on different occasions. My recollection is that they were prepared, though not perhaps in these exact words, by Major Wilber, who at the time had the main charge of the patent matters of the company.

24 x-Q. And it is a fact, is it not, that the scope of that first claim, as set forth in this newspaper publication, is broader than that of either one of the three following claims?

A. That speaks for itself. I could not tell without carefully comparing them.

25 x-Q. Will you kindly examine the document and see?

A. I will read the claims and you can put your own interpretation on them. (Witness reads claims to counsel).

26 x-Q. At the time when you prepared this statement of the salient features of your three so-called "fundamental" patents, did you not consider this claim 1 as broader in its scope than either one of the other three claims set forth in said statement?

A. Really I don't remember.

27 x-Q. Have you no opinion in regard to it?

A. Do you mean as a lawyer or as a witness?

28 x-Q. I mean in the capacity in which you have presented yourself here to-day?

A. I have not.

29 x-Q. Does it seem to you in reading these claims

that either the second, the third or the fourth is as comprehensive as the first?

A. The first claim is as follows:

"1. An electric lamp having a continuous conductor (without regard to its material, resistance or mode of preparation) and an exhausted glass enclosing globe."

The other three claims are as follows:

"2. An electric lamp having a continuous carbon conductor (irrespective of its material, &c.) and an exhausted enclosing globe."

"3. A filament of carbon of high resistance secured to metallic wires (*i. e.*, the leading in wires)."

"4. The method of manufacture, *i. e.*, first separately forming the enclosing globe and the support for the carbon, and then fixing the carbon upon the latter, uniting the globe and then exhausting."

The first two claims seem to me to be the only ones which can be properly compared. They both refer to an exhausted glass globe. In my opinion the first claim is broader than the second. The third claim does not refer to a globe, which is one of the principal features of the first two claims. The fourth claim relates merely to a method of manufacture. I cannot compare the third and fourth claims with the first, but I can compare the first and second, and my opinion is that the first claim is broader than the second.

30 x-Q. Is not the first broader than either the third or fourth in this respect, that is to say, that the third is limited by the condition that the burner be made of carbon, while the first is not so limited?

A. The first claim refers to a continuous conductor without regard to material; the third claim refers to a filament of carbon of high resistance; the fourth claim refers to a carbon. I am not an expert, but it seems to me that a conductor without regard to material is broader than a conductor made of carbon.

31 x-Q. Was not one consideration that weighed materially with your company in causing them to delay bringing suits against the United States Company, the fact that one of the prominent counsel of the company had serious doubts as to the validity of the company's

patent, No. 223,898, or at any rate, as to the ability of the company to sustain the charge of infringement of that patent against the United States Company?

A. If you will tell me the name of the counsel, I shall try to refresh my recollection in that regard.

32 x-Q. It is currently reported that Mr. Lowrey had for a long time serious doubts as to the ability of the Edison Company to sustain that patent against the United States Company, and that that was one of the reasons why suit was not earlier brought. He is the gentleman to whom I refer.

A. So far as Mr. Lowrey is concerned, the position occupied by him was squarely the reverse of what you state. My recollection is that from first to last, that is to say, from the time I first went with the Edison Company until the present moment, Mr. Lowrey has uniformly stated his opinion to be that this patent was good and could be sustained in Court against any infringer—not only that, but I remember distinctly that on many occasions when I was vice-president of the company, Mr. Lowrey urged upon the officers of the company the importance of litigating this patent. I think the only doubt that he ever expressed was with reference to what effect the termination of foreign patents might have upon our patents owing to Section 4887, but he always expressed confidence that when that question was brought properly before the Courts the decision would be in favor of sustaining the American patent. In fact he gave me a written opinion to that effect very early in the history of our company in which he expressed those views.

33 x-Q. Was it not on Mr. Lowrey's advice that the patent was returned to the Patent Office to have a correction made in regard to the term for which it was issued, which correction was made in December, 1883?

A. I am not certain, but probably it was, because he was at that time giving special attention to the question of law involved in that matter, and as to the effect of the expiration of the foreign patents.

34 x-Q. Is is not also a fact that both Mr. Lowrey and yourself were of the opinion that without that

change in the patent, it would be extremely perilous to put it in suit?

A. My recollection is that it was done simply as an extra precaution to avoid any possible danger in that regard.

35 x-Q. Didn't you in an affidavit made by you in connection with the proceedings to effect that change in the patent, say in substance that your company had been advised by counsel that that change was necessary?

A. I think very likely, but do not remember. I see nothing in such a statement that would conflict with my recollection as already given.

36 x-Q. You have made reference to certain litigation in Paris. Were there not several of the Edison Patents involved in that suit?

A. I don't remember.

37 x-Q. I will make my question more definite, with a view to refreshing your memory. Was not there involved in that suit a French patent, which embodied substantially the matter which is found in the United States Edison Patent No. 227,229; also a French patent which embodied matter found in what is known as the Edison Paper-Carbon Application in this country: and thirdly, the French patent to which you have already referred? And is it not a fact that when, under the proceedings of the French Court, the controversy was referred to experts selected by the Court, they made a report in substance that the Maxim lamp did infringe the patent relating to the paper carbon, and did not infringe the patent which you say corresponds to the patent here in suit, and did not infringe the patent corresponding to the American Patent No. 227,229; and is it also not a fact that on the making of that report the suit, by the agreement of the parties, was discontinued, the taxable costs of the suit being divided between the two parties?

Objected to as immaterial.

A. I really cannot answer yes or no to the several

distinct questions embraced in this interrogatory. I do, however, remember the fact that we took advantage of that French suit to get before the public a statement to the effect that our principal patent, and notably our filament patent, controlled the incandescent lamp. As to the many details contained in your question, I really have no recollection, as I have not thought of them for many years.

38 x-Q. I must again ask you whether, in any of those statements given to the public, either in connection with the French litigation or otherwise, you asserted that the so-called Filament patent was *the* patent which you deemed to be controlling? Did you not always, in those statements, couple that patent with others?

A. I do not remember, but I do recall that we always made a feature and a prominent one of the filament patent.

39 x-Q. But not more prominent than others referred to in the same documents?

A. I could tell better if I saw the documents.

40 x-Q. In the absence of the documents you will not then make such assertion?

A. As regards unknown documents I make no assertions.

41 x-Q. Was any judgment ever made in that French suit?

A. I have not heard this matter mentioned for years, nor have I thought of it for many years, and to the best of my recollection I do not know how the case was disposed of.

42 x-Q. Was that suit brought against the United States Electric Lighting Company?

A. If you will permit me to say, our company here not only did not own the European patents, including France, but had no interest in them and no control over them or over the management of the companies owning them in any way whatever, and never had. We had nothing to do with the patent litigation abroad, and I do not remember against whom the suit was brought, save and except that it was against an incandescent lamp which was well known to us at that time, called the Maxim lamp, manufactured by the United States Electric Lighting Company.

43 x-Q. In the document signed by Spencer Borden, under the date of November, 1883, to which you have referred, and which has been offered in evidence by complainant's counsel, I find this statement: "Many of those interested in the Edison Company were urging its officers to deal summarily with parties who were pirates of Mr. Edison's invention." Do you know who the parties referred to by the expression "many of those intereste in the Edison Company were urging," etc., were?

A. I remember distinctly that Mr. Borden was one, and I think Mr. Lowrey was another.

44 x-Q. And Mr. Borden held what business relation to the Company?

A. He was in charge of our New England department.

45 x-Q. Now is it not a fact that prior to that date, to wit, November, 1883, very serious complaints were being made to the Edison Company on account of the introduction into New England of the incandescent lamps of the United States Electric Lighting Company, and in point of fact, was not that competition of the United States Company a serious business matter with the Edison Company?

A. Eliminating the word "serious" from your question, I would answer it as follows: Our agents found it uphill work to introduce this new invention, and they attributed the difficulties sometimes to one cause and sometimes to another. We gave their complaints consideration. When they complained that the Maxim lamp was injuring them, my recollection is that I personally had every Maxim plant in the United States inspected by representatives from our Company, and that, from the written reports made by these inspectors, I prepared a document which was sent to our various agents showing that the Maxim lamp was not making headway in a business or serious sense. The ground we then took was that all of our energies should be expended in developing our business, and that they should not be dissipated by litigation, especially when there was no substantial business progress being made by anybody else.

46 x-Q. Did you not consider it a somewhat serious matter that the United States Company should take from you in open competition such contracts as that for lighting the Post-office and Court House in the City of New York, the Post-office and Court House in Philadelphia, the State Capitol at Albany, the Post-office at Chicago, the Post-office in St. Louis, and the steamboats, eight in number, of the Pensylvania Railroad Company on the North River, and other contracts of that kind?

A. We felt that a few post-offices or steamboats were hardly worth considering, especially when the work was poorly done by those who, by means best known to themselves, succeeded in getting the contracts. A few isolated plants, poorly installed and running unsatisfactorily to the buyer, gave us no particular alarm, certainly not enough to warrant the trouble and expense of litigation.

47 x-Q. Did you not, as one means in your attempt to induce the Pennsylvania Railroad Company to give you the contract on their steamboats, threaten them with a suit in case they adopted the Maxim lamp of the United States Company?

A. I do not remember any threat, but I do remember this, that the adoption by the Pennsylvania Road of the Maxim lamp on a ferry-boat received our unusually careful attention. Mr. Edison resided at Menlo Park on the line of that road. His laboratory was there. He was the means of contributing business to that road, and had always been on friendly terms with the officers. I recollect too, that there were certain peculiar and personal reasons why Mr. Edison felt friendly towards that road, and why he supposed they felt friendly towards him. When therefore, they adopted the Maxim lamp in spite of our offers to give them the Edison lamp on similar terms and conditions, careful consideration was given to the matter by us, and my recollection is, that some unusual course was taken by us, but whether it was the serving of such a notice as you stated I do not remember.

48 x-Q. To Mr. Edison, then, it was a matter of grave disappointment that his lamp was not adopted by the Pennsylvania Railroad Company, was it not?

A. My recollection is that the Pennsylvania Company took the position that in their business they held patents in contempt. I might almost say that if two like devices were presented to them, one patented and one not, they would choose the latter. It was not only on account of his patents that Mr. Edison felt some disappointment, but it was also—and I think more particularly on account of his personal relations with the officers of the company, which had always been very friendly, and he thought that in consequence of those relations they ought at least to treat him as fairly, even disregarding all patents, as they would treat anybody else.

49 x-Q. This "unusual course" which you say followed the selection by the Pennsylvania Railroad Company of the Maxim lamp in preference to the Edison, was a proceeding, whatever its nature may have been, that emanated from the Edison Company and not from Mr. Edison, was it not?

A. So far as any official steps were taken, I answer yes to your question. Mr. Edison was never an executive officer of the Edison Electric Light Company.

50 x-Q. These lights were put into the Pennsylvania Company's boats in the year 1881 and 1882, I think?

A. I am not certain. It was about that time.

51 x-Q. Now, is it not a fact that the Edison Company regarded the boats of the Pennsylvania Railroad Company as a prominent place for the display of incandescent lamps in the years 1881 and 1882, and that the company itself, as well as Mr. Edison, felt a serious disappointment in a business way, that they lost the contract for those boats?

A. There is no doubt that at that early date these boats were a good advertisement. We would rather have had them than not, but our principal grievance

after all, was our feeling that the Pennsylvania Road, without adequate business cause, so far as we could ascertain, selected for their ferryboats a lamp other than that of Mr. Edison, notwithstanding the relations of Mr. Edison with the road and its officers as I have stated.

52 x-Q. You have in former answers implied that the boats of the Pennsylvania Company were badly lighted by the Maxim lamps. Is it not a fact that those lamps are still in the service of those boats, and that the boats are well lighted?

A. It is nine years since the United States Company began to light the boats. Those boats are well lighted in this ninth year by somebody, but I am not sure by whom. I believe, however, that it is by the United States Company.

53 x-Q. Are you prepared to say that the lighting on these boats in the first years after the introduction of the Maxim lamp was not substantially as good as the lighting done under similar conditions by the Edison Company at that same time?

A. That depends upon what you mean by "similar conditions."

54 x-Q. I refer to ferryboats?

A. Your words "first years" are somewhat vague, but speaking of the time when the installation was first made on their first ferryboat, I remember that we had the running of the plant watched; that reports were regularly made as to how the plant run, and that the fact of the poor running of the plant was used by us with the Pennsylvania Railroad officials to try to induce them to take the Edison lamp. I have no documents to sustain this assertion, but my recollection about it is clear. Now as to how well the Edison plants were running at that time on ferryboats, I can only say that I recall no complaints as to such plants. It would not have been difficult for us at that time to install a successful running on the ferryboat in question.

55 x-Q. Perhaps you had no plants on ferryboats at that time, say, in 1881, 1882 or 1883?

A. Very likely not; I don't remember. But there were no especial obstacles in connection with a ferry-boat plant.

56 x-Q. Is it not a fact that in the year 1882, the Edison Company had an electric lighting plant in the New York Post-office and Court House, and that after a careful comparison instituted between the Edison lights and the Maxim lights, the Edison plant was ordered out of that building, and a Maxim plant, manufactured by the United States Electric Lighting Company, substituted, and was not that regarded by the Edison Company at the time as a serious business matter; further, was there not in connection with that transaction a very sharp and bitter business competition between the two companies?

A. I remember that we had a plant in the Post-office, but not in the part of the building used by the courts. I remember that we regarded it as a good advertisement. I do not recall the reason why the use of our plant was discontinued, but my impression is that it was not on its demerits. These small plants had really no commercial value. At the best the profits were not worth considering. In those days we were engaged in developing our business. We knew that we were the first in the field; that the field was vast, and that all of our energies should be adapted to covering the ground with the utmost possible rapidity. In a few isolated cases like the ferryboat and the Post-office, and possibly in other isolated instances, we gave undue attention to trifling matters on account of special reasons, but after all, our main object was to waste no time in side issues, but to develop the larger possibilities of the business.

57 x-Q. Did not some of these Post-office contracts amount to between fifty and seventy-five thousand dollars each?

A. I do not remember; but even if it were so, the cost of a plant is one thing and the profit made on it is another. In those days when few people had confidence in electric lighting, and when we had to get it introduced in conspicuous places on the best terms we could, we installed plants in desirable situations for other considerations

than that of money. We had a large capital invested in our business; our stock was selling at a high price; no factories were in existence to manufacture the whole or any part of our plants; and our entire energy was bent on the rapid development of our business so that we might at an early day return profits to our stockholders.

58 x-Q. Is it not a fact that in order to secure contracts in some of these conspicuous and, therefore, very desirable places, you reduced your bids materially from what they would have been had it not been for the rivalry of the United States Electric Lighting Company? Particularly, was not this so in several of the post-offices and other Government contracts that were let prior to the year 1885?

A. I remember that our feeling was that while the United States Company was not a competitor in a business sense they were skillful advertisers, and had influential men, including capitalists, connected with their management and in their board. They made it a point to secure installations at any price, and, as we believed, to run them at their own expense, even at a loss, for the purpose of advertising. We discovered that buyers from them were frequently influenced by other than such business considerations, as it appeared to us, but the United States Company met us at such a very few points and their total business was so small that we gave the matter no serious consideration, save and except at conspicuous points where advertising was a *desideratum*. It was at those points that they principally attacked us—notably post-offices.

59 x-Q. Were there not instances where the United States Company secured contracts in competition with the Edison Company, even where the prices of the United States Company were higher than those of your Company?

A. That illustrates emphatically what I mean by peculiar reasons other than those of a business nature—that is to say, if such was the fact.

60 x-Q. Might not another fair and honest interpretation of such fact (which fact I understand you to

admit) be that purchasers considered that they were getting a better article from the United States Company than from the Edison?

A. If any purchaser considered the matter in that way, it is equally fair and proper to say that he did not know what he was doing. Indeed, the fact is, that at that early day all purchasers had really to rely upon the say-so of somebody else.

61 x-Q. Your company was a competitor with the United States Company for the contract for the Post-office building in Chicago, and also the Post-office building in St. Louis, was it not?

A. I do not remember. Personally I had no charge of sales of plants.

62 x-Q. You do remember the fact, however, do you not, that in the year 1882 there was a very bitter controversy between the two companies in regard to the lighting of the Capitol at Albany, and that the contract was finally awarded to the United States Company?

A. I remember that we did not succeed in getting the contract to light the Capitol, and that we could not understand why, on business principles, we failed to get it.

63 x-Q. You actually put a plant into that building and run it in competition with the plant of the United States Company, did you not?

A. This was another of these advertising plants that I have spoken of. I do not remember the details of the event, but I think we had a plant in the Capitol, and that there was some other plant there at the same time. I have not heard this matter mentioned nor have I thought of it for many years.

64 x-Q. When Mr. Borden made complaint of the operations of the United States Company in his territory, that is, in New England, is it not a fact that some of the United States Company's plants had gone into cotton mills at Lowell and Lawrence and other parts of New England?

A. Really, I don't remember, as it has been many years since I have heard any of these things mentioned or thought of them.

65 x-Q. Could you not refresh your recollection in a moment by referring to some of the publications of your company lying close at hand?

A. I can. I hold in my hand a printed circular issued by the Edison Company on December 10, 1883. It was prepared by me. The first sentence is as follows: "The following list of decrepit Maxim plants is believed to be absolutely correct." The circular then goes on to state upon what information the list was prepared. That circular shows that there were Maxim plants then installed in manufacturing establishments in New England, as you state. It also shows that some of them were decrepit. The fact that they were not serious competitors in a business sense was the main reason why we did not think they were worth suing in court, and why no lawsuits were brought on our patents prior to that time.

66 x-Q. Referring to your interviews with Mr. Flint, are you willing to state under oath that you ever said to Mr. Flint that the principal patent owned by the Edison Company relating to incandescent lamps was the patent now in suit; in other words, whenever you mentioned that patent to him, was it not in connection with other patents, in like manner as you coupled several patents together in the formal printed notices that you served upon the United States Company and in the interviews which you had with newspaper reporters?

A. I do not remember any mention of this specific patent, but I have no doubt that I stated what our claims were as regards incandescent lamps; that is, I mean that this subject was so frequently talked over in our business that our principal claims touching the lamp became everyday expressions, and I have no doubt that in my talks with Mr. Flint as well as on all other occasion, in speaking of our business I mentioned these things.

67 x-Q. In your direct testimony, in answer to question 4, I find a statement by you as follows: "Formal notices of infringement, in order to fully preserve our legal rights, have been served upon various electric

light companies"; which statement is taken from your report to the stockholders of the Edison Company made in October, 1883. So far as the United States Electric Lighting Company is concerned, were these formal notices in the form of letters addressed specifically to that company, or were they in the form of printed circulars, copies of which were sent to the United States Company as well as to the other electric lighting companies?

A. The notice of November 9, 1882, and which is Defendant's Exhibit No. 2, page 2196 of the printed record in this case, is addressed specifically to the defendant. The earlier notice, which I believe was dated June 12, 1882, and which is Defendant's Exhibit No. 1, found on page 2191 of the printed record in this case, does not appear to have been addressed to the defendant, but my recollectfon and belief is that as regards both of these notices, they were not only addressed to the defendant, but were served on it by personal service, and that the party who made the service filed away with our company an affidavit to that effect. I recollect distinctly that our company, having adopted the policy of going ahead with the sole object of developing our business and without stopping to expend our time and forces in litigation, attempted to give such notice of our legal rights as would show that there was no laches on our part, in case, at a later date, we found a competing company of sufficient importance to sue. These notices, and I believe other similar notices, were served for the purpose of maintaining our legal rights. My recollection is that they were served by advice of counsel and under my personal supervision. I am not certain about the affidavits of service having been made, but it is my recollection and belief that such was the case.

68 x-Q. Do you remember any notices served upon the United States Electric Lighting Company that were more definite and exact on this matter of infringement than the two to which you have made reference in your last answer?

A. No, sir.

69 x-Q. Did you by either of the notices to which you have just referred as having been served upon the United States Company, intend to indicate to that company that they were infringing any particular patent owned by your company, and if so, what ones?

A. The notices speak for themselves, and are meant to warn parties proposing to engage in the business of incandescent electric lighting not to do so. I do not find that the patent in suit is emphasized in these notices.

70 x-Q. Did you at that time consider that those notices served upon any particular company were sufficient to preserve all the legal rights of your company (so far as any notice could preserve them) in case it should subsequently be found that the company served was infringing some one of the very numerous patents named in the notices?

A. Our object was to serve notices which would give just that result. My belief is that we served other notices besides these two but I cannot produce them. My further belief is that these notices were intended to accomplish the result you speak of as regards the patents mentioned, of which the patent in suit is one.

71 x-Q. Do you now say under oath that you did serve other notices upon the United States Company?

A. To the best of my recollection we did, but I am not certain of it. I do recollect this, however, that we kept up a continual fire all along the line, so to speak, on this subject, in conversations between officers and directors of the two companies, in correspondence between agents or respective sides and in the newspapers. We took occasion at all times to emphasize the fact that Mr. Edison's patents gave us the monopoly of the incandescent lamp and we always spoke particularly of the filament patent as one of the most important.

72 x-Q. If in fact you did serve other notices upon the United States Company than the two to which you have made reference, was it upon the theory that those two formal notices were not sufficient to accomplish the purpose for which they were designed?

A. No, sir. If other notices were served they were doubtless of the same general kind; for instance, the second notice already referred to states that the patents included therein are "in addition to" the list of patents included in the earlier notice. My recollection is that we served later notices in which we covered all of our patents up to various dates, including not only those embraced in these two notices, but also those which were issued subsequently. In other words, it was our intention to issue circulars from time to time as patents were granted so as to give people legal warning.

73 x-Q. I understand you to assert, a few minutes since, that the belief of the Edison Company at the time of issuing these circulars was that nobody could make an incandescent lamp without infringing some of the patents owned by the company. Was that the view of the officers of the Edison Company at that time, and has that always been their view?

A. Our view was that the Edison patents gave us a monopoly of the manufacture of a commercially successful incandescent lamp, and we always regarded the Maxim lamp as an infringement of our patents, although it was not necessarily a commercial success at that time.

74 x-Q. And you hold to-day, do you not, that it is impossible to make a commercial incandescent lamp without infringing some of the patents owned by the Edison Company?

A. We do.

75 x-Q. And you also hold, do you not, that it is impossible to-day to make a commercial incandescent lamp without infringing the patent in suit?

A. I am not an expert on this subject, nor am I an executive officer of the company, but my belief is that the company takes the position you state in its business dealings.

76 x-Q. In your answer to question 4 I find that you are quoted as saying in the year 1882 that the Edison Company would bring suit against the Swan light as soon as the Brush Company would offer it for sale.

Please state if such suit was ever brought, and if so, when?

A. The Edison Electric Light Company brought a suit against the Swan Incandescent Electric Light Company in May, 1885.

77 x-Q. How extensive had the business of that company become at the time when that suit was brought?

A. I had ceased to be an executive officer of the Edison Company prior to that date, and I can answer your question only with regard to the time when I ceased to be an executive officer, namely, October, 1884. Even as regards that date my recollection is not strong, but my impression is that the Swan lamp, like the Maxim lamp, had never been a serious competitor in our business, nor one worth suing in the courts. In the extract from the interview quoted in the question just asked me I find the following words immediately after the words you quote. They are these: "The Edison Company will also begin suit against the United States Company should the Maxim lamp interfere with the business of the Edison Company." We took a similar position as regards the Swan lamp, namely, that we would not bring suit until the infringing lamps became worth considering from a business standpoint, and that in the meantime we would devote our entire energies to developing our business. Whether that policy was changed after I ceased to be president of the company, which was in October, 1884, I do not know.

78 x-Q. While you remained an executive officer of the company how large a volume of business did you consider it was necessary for an infringing company to do before it would have been sound business policy to bring suit to secure an injunction?

A. There were other elements in this question besides the mere size of business done by an infringer. When I joined the Edison Company in 1881 its entire business was done by one clerk, with a single desk, and I think I was the second person who ever received pay for services rendered that company, except the patent lawyers. From that small start the business developed with such rapidity that we could not secure men with the necessary training to handle it. Our time and attention were engrossed in finding men to do our business, in starting our factories, and in laying the foundation for this entirely new and difficult industry. We could not stop at that time to waste money and energy in litigation against insignificant infringers. Our policy was to first make ourselves strong, and meantime to let imitators alone until they really became competitors affecting our business.

The reason why we did not immediately sue the present defendant, as well as sue many other makers of lamps who started in business but dropped by the way, was, first, that our time could be better employed, and, second, that no infringer was then worth suing. So long as I served the Edison Company in an official capacity, the defendant had not become strong enough to be worth suing. I do not remember that I ever fixed any volume of business to be done by them which would mark the time when we should begin suit. Possibly my successor may have done so, for the suits were begun soon after I ceased to be an executive officer.

79 x-Q. Is it not a fact that long before you ceased to be an officer of the Company, your selling agents and the managers of your various districts, and those who were interested in the corporations who were your licensees, repeatedly urged you to bring suit against the United States Company because of the competition which they had encountered from that Company?

A. The United States Company was always a good advertiser and made a good deal of noise, but they really did but little business. At least we thought so. Our agents used to complain of a hundered different things. This is always so in a new and difficult business. In the electric lighting business everybody from the president down was in the business for the first time. There was no precedent, there was no skilled labor, everything was strange. Our agents were easily alarmed and sometimes frightened by the advertising methods of the defendant. It was for this reason that we decided to get to the bottom and find out the facts. That was done, as appears by the circular of December

10, 1883, which I referred to a short time ago. I believed that the defendant made more noise than they did business. This circular proved that to be the case, and that fact being proven, our agents appeared to be satisfied. At any rate, the information which was the basis of this circular, confirmed the judgment of the managers of our Company, that the Maxim lamp was not worth suing at that time.

80 x-Q. I still press the question, whether the agents of your Company and others who were interested in the Edison light did not repeatedly urge you to bring suit against the United States Company, and whether these solicitations were not based upon the alleged difficulties which they encountered by reason of the competition of the United States Company; whether they did not allege on that ground difficulty in making sales, and also difficulty in obtaining the prices that they thought they might otherwise obtain for the lamps actually sold.

A. The United States Company were good advertisers and were not modest in making claims. Each agent of ours knew that the Maxim lamp amounted to nothing in his own locality, but he was always hearing that it was successful elsewhere. Our object was to get at the facts and to show our agents that what was true of each locality was true of all. They did complain of the competition of the agents of the Maxim lamp and of their representations, and it is quite likely that our agents asked us to bring suit. But we satisfied our agents that the cure was not in litigation, but in exposing the falsity of the claims of the selling agents of the Maxim lamps. That was done by the circular referred to.

81 x-Q. The event proved that that was not the correct cure, did it not?

A. Which event do you refer to?

82 x-Q. I refer to the growth of the business which apparently necessitated your bringing suits?

A. There were two opinions about bringing suits on patents in the early history of our business. The lawyers, and notably Mr. Lowrey, and I may say also myself, wanted suits brought at the start, but the business men, and especially Mr. Edison, thought that no then-infringer was worth suing; that we could not afford to dissipate our energies; that all we need to do was to preserve our legal status by adequate notice to infringers, and that we could bring suits at a later day. Answering more specifically your question as to the event, I should say that our experience in this particular suit shows that if we had begun suits at an earlier date we would probably not have done anything else. The entire force which we then had would have been principally occupied in carrying out this suit, taking our experience for the last year as a criterion. To that extent Mr. Edison was right. On the other hand, I think that the event also shows that it is very unfortunate, looking solely to the question of our sustaining our legal rights, that we did not sue at the start and thus secure at an early day the monopoly which we now expect to obtain in this suit. Our business men, however, were stronger than our lawyers, and no suits were brought. All that we aimed to do was to preserve our legal rights by adequate notice.

83 x-Q. In the paper signed by Spencer Borden under the date of November, 1883, and which has been made an exhibit in this case, reference is made to two other papers, one of which is "A paper sent from the Office of the President of the Edison Company for Isolated Lighting to the Agents of that Company, informing them as to the apparent business of the Company, which sought recognition as a competitor," and the other of which appears to have been a reply to such first named paper, made by the New England Weston Electric Company. Have or can you furnish either of those two papers?

A. I cannot furnish the paper issued by the company owning the Maxim lamp, which is the second of the papers referred to. My recollection is that it was a private document issued for circulation only among the agents of the Maxim lamp. I do not remember what the paper was, but I recollect the fact that there was such a paper.

As regards the other document referred to in your question, I recollect very well what it was. It was a statement of broken-down Maxim plants substantially like that which I have already referred to, to wit, the Edison circular of December 10, 1883. I remember that this earlier list of broken-down Maxim plants was criticized as not being full and accurate. I therefore sent out a circular to our agents, sending at the same time a copy of the earlier paper, and asked them to take especial pains to verify every statement made in the earlier paper and to give me actual information about all Maxim plants in their several agencies. This action on my part resulted in the last-named circular of December 10, 1883. The earlier paper I have no copy of. I believe I have not seen a copy of it or heard it referred to before for many years certainly not for five or six years.

84 x-Q. Looking at the "memorandum of decrepit Maxim plants" sent out by the Edison Company for isolated lighting under date of December 10, 1883, I understand that you personally were responsible for the preparation and issuing of that document?

A. I was responsible for it only to the following extent: Our agents had complained because we did not sue the Maxim lamp. Our reply was that it was not worth suing. Their rejoinder was that the Maxim agents were competing, and our reply was that facts would show that they were not really competitors in a business sense. In order to show the truth of this, I asked our agents to personally inspect, or to have inspected by responsible parties, every Maxim plant in their several agencies. I urged them particularly to be accurate and truthful, because the information given by them would be used in a public circular, and it was important that we should make no statement which could be contradicted. These examinations by our agents were made; they made their reports to our office, and thereupon the circular of December 10, 1883, was prepared under my direction. As the circular states on its face, it was an honest attempt to tell the strict truth about the Maxim plants. I had no reason at the time to doubt the accuracy of our agents' reports upon which this circular was based, and my recollection is that I have never had any reason to doubt it.

85 x-Q. If that document was intended for a public circular, and if, for this reason, you instructed your emissaries and spies to be extremely careful and thorough in their observations and truthful in their reports, so that you might feel sure that the statements contained in your circular, when made public, could not be refuted by those whose business interests you were intending thus to attack, why did you put this statement into the circular, "This memorandum is intended for private distribution only among our agents, and they will please treat it accordingly"?

A. In the sense in which I used the word "public" my statement is correct, although apparently not so. The fact was, as stated by Mr. Borden in his circular of November, 1883, that our object in getting information was "that it might be ascertained if the losses by business going to the Weston-Maxim combination were of sufficient importance to justify the necessary expenses involved in suing them." A common taunt on the part of the Maxim agents was to ask why we did not bring suit if our patents were controlling. Our agents had to meet this taunt in dealing with customers. They had either to say that we would sue, or to give good reasons why we did not. Our object in getting at the facts contained in this circular, was to give our agents the means of stating why we did not sue. We wished to give them facts, namely, that the Maxim plants were not commercially successful, and that the United States Company was not a competitor in a business sense. It is true that the circular itself was not for public distribution, but it was certainly intended that the statements made in it should be made public. In fact, the only object of getting this circular out was to give our agents the means of satisfactorily meeting the claim of the agents of the Maxim lamp, namely, that if our patents amounted to anything, we would sue the United States Company. Therefore, I say that while the circular itself, probably owing to questions touching libel and other

legal questions which might have presented themselves at the time, was not to be publicly distributed, nevertheless the subject matter of the circular—the allegations contained in it which we believed to be true—were to be made public use of. With this explanation I beg to modify the answer last given above.

86 x-Q. In other words, as I understand you, you thought it would be better to manage this campaign of slander in such a way that your *agents* would become liable to actions for *slander*, rather than to subject *your company* to an action for libel; is that what you mean?

A. It was not necessary to be a "spy" in order to inspect a Maxim plant, although it is true that the agents of the Maxim Company were afraid to have their plants seen by any one who understood the business. No doubt in the combat of trade, challenges were made which legitimately led up to an exhibition by the buyer of a Maxim plant, of the plant in question. This is so in all businesses, and the agent who does his duty is, in my mind, neither a "spy" nor an "emissary."

As regards the epithets of "slander," nothing was stated in that circular which we did not honestly believe was true. Nothing was stated which it was not fair and honorable to say in business competition. The circular was doubtless a hard blow to the United States Company. It is rather to our credit, I think, that we were charitable enough not to make it public. Telling the truth in honest business is not libel or slander.

87 x-Q. Why do you claim for yourself credit on the ground that you were "charitable enough not to make your circular public," if, as you have previously stated, it was your intention that the alleged facts contained in the circular should be given to the public by your agents?

A. Telling the truth to an isolated customer in one's counting room is a different thing from publishing the same thing in every newspaper in the world. Between these two extremes there is a wide domain wherein individual taste or judgment must control. Personally I would prefer to use such damaging information as the circular contains, only where it was necessarily needed in business transactions, instead of spreading it broadcast for the general defamation and injury of the Maxim lamp. However, whether or not that was charitable is a matter of individual taste.

88 x-Q. Then, as I understand you, your policy in instructing your agents, as you did in the circular, that the circular was "intended for private distribution only," and that they were to treat it accordingly, was to enable them to use the "damaging information" which it contained in their business dealings with "isolated customers" (by which, I suppose, you mean prospective purchasers), and not to permit this volume of "damaging information" to be exposed publicly where agents of the United States Company could make fair and honest reply to it. Was that your object?

A. No, sir.

89 x-Q. Why, then, were you apprehensive that this circular, if it were made public, might subject your company or yourself to an action for libel?

A. I am a lawyer and not a business man. When the Edison Company had me as an executive officer they had a man with the instincts and caution of a lawyer. I acted just as I would have advised a client to act. I erred on the safe side.

90 x-Q. Personally, do you know whether the statements contained in the circular in question in regard to the Maxim plants were true?

A. Personally, I do not. It is barely possible that in one or two of the plants referred to I may have had personal knowledge, but I doubt even that. To answer your question as truthfully as I can, I did not, personsonally, make any inspection of these Maxim plants, nor did I personally prepare a single report about them which was made the basis of this, but, personally, I can say this, that nothing is therein contained which I did not believe to be true.

91 x-Q. Is it not possible that some statements were made in the various reports of your emissaries and

spies, from whose reports you compiled the body of this circular, which were at variance with the truth?

A. Substituting the word "agents" for the words "emissaries and spies," I reply that it is possible but not probable.

92 x-Q. Is that opinion based upon the fact that under your administration the Edison Company never employed agents who were not truthful?

A. We never employed agents *because* they were untruthful.

Signature to the foregoing deposition is waived.

Counsel for defendant now offers in evidence a copy of a letter purporting to be a letter dated April 1st, 1884, and addressed by the Edison Company for Isolated Lighting, a licensee of the complainant herein, to the Hon. Charles J. Folger, then Secretary of the Treasury of the United States, the same being in words and figures as follows:

"The Edison Company for Isolated Lighting,
65 Fifth Avenue,
New York, April 1st, 1884.

Hon. Charles J. Folger,
Secretary of the Treasury,
Washington, D. C.

Sir—We take the liberty of calling your attention to proposals recently tendered by ourselves and by the U. S. Electric Lighting Co. for furnishing electric lighting apparatus for the Post-office and Custom House Building in Chicago, Ills. The specification called for 700 incandescent lights, and this Company presented a bid calling for two 400-light dynamos, engines and appurtenances for the sum of $23,600. Our Chicago agent has been informed that the bid of the U. S. Company was as follows:

700 Incandescent Lamps	$17,980
20 Arc "	3,740
	$21,720

"Prior to this the Department asked for bids for the Post-offices in Philadelphia, Boston and St. Louis, and, as you are already aware, the U. S. Company underbid us both in Philadelphia and St. Louis, and were given a contract for those two orders, while this Company received the order for Boston. If, therefore, the U. S. Company are given the order for Chicago, they will have St. Louis, Chicago and Philadelphia, leaving our Company in Boston only.

In view of the fact that the first cost of an electric plant has no bearing whatever on the cost of operation, and assuming that the object of the Department is to ascertain by practical trial of the two systems which is the most economical, we would respectfully request a full consideration before a decision in the Chicago matter is reached.

If the Department were considering the purchase of a steam engine, a small difference in first cost would not be regarded as important in comparison with its economy of operation or the amount of coal it would require to develop a given power. For the same reason we claim that the adoption of our system by the Government will be a measure of economy, even at the expense of first cost, since there is no other system of electric lighting wherein the cost of operation has been reduced to so low a figure as with ours. This fact has been attested by manufacturers and others in various parts of the country where a practical test has been made of both systems, and the Edison been found to be the most efficient and economical and the most satisfactory in every detail. Moreover, where scientific comparative tests have been made with a view to determine this very question of economy of operation, the Edison system has always been proved to be the most efficient and economical. We refer particularly to the report of the Paris Electrical Exhibition of 1881, and to the recent Industrial Exhibition in Cincinnati. In the State Capitol at Albany, N. Y., the U. S. Company put in a plant

"consisting of 325 incandescent and a few arc lamps nearly two years ago, but it has never been in continuous use for any length of time. The Judges of the Court of Appeals instituted a thorough investigation, the result of which was that they sent a written request to the Capitol Commissioners requesting the introduction of the Edison system in their Department. This petition was signed by six of the seven Judges. The U. S. Company asked for $95,000 for the purpose of continuing their system throughout the building, and that amount was inserted in the Appropriation Bill. The Bill was referred to the Finance Committee of the Senate, and after a thorough and exhaustive investigation the entire amount was stricken out. Through a strong personal and political influence they finally succeeded in obtaining an amendment to the bill appropriating $15,000 for work already done, but with a further amendment that no more money should be expended on their system.

As a practical precedent for what we are about to ask, we would beg leave to quote the action of the Dominion Government in Ottawa, Canada.

They desired to light the lower house; in accordance with the Dominion laws they asked for proposals. The U. S. Company underbid us and were given the order. The chief engineer of the Parliament Buildings who had previously investigated the subject was so convinced as to the superiority of our system that we were requested by Sir Hector Langevin, Commissioner of Public Works, to light the Senate Chamber on condition that the price should be the same as the bid of the U. S. Company, and that both systems should be subjected to a thorough scientific test for a period of thirty days. To this we consented; the test has recently been completed, and although we have not yet received the official report, we are today in receipt of a dispatch from one of our representatives in Canada informing us that the test "has been completed, and we have come out ahead in every detail.

We have taken the liberty of intruding thus far on your valuable time, in order to recite these facts requisite to substantiate our claims, and would now respectfully request that we be awarded a contract for lighting the Chicago Post-office and Custom House on the grounds of merit generally, and specially on the ground that with the U. S. Company's light in Philadelphia and St. Louis, and the Edison light in Chicago and Boston, the Department will be better enabled to determine upon the best system to be adopted.

In order that the Department may be in a position to grant our request, we will offer to furnish the plant as per specifications at the same price as the bid furnished by the U. S. Company.

We remain, sir,

Very respectfully yours,

THE EDISON COMPANY FOR ISOLATED LIGHTING,

By F. S. HASTINGS,

Treasurer."

Counsel for complainant admits that the letter is a correct copy of a letter dated and addressed as stated by counsel for defendant, subject to the objection to the introduction of said letter in evidence as immaterial, irrelevant and incompetent.

NEW YORK, August 7, 1890.

FRANCIS R. UPTON, a witness produced on behalf of the plaintiff, being duly sworn, testifies as follows: in answer to questions by Mr. Dyer.

1 Q. What is your name, age, residence and occupation?

A. Francis R. Upton; residence, Orange, New Jersey; my occupation, manufacturer of Edison lamps; age, 38 years.

2 Q. How long have you been engaged in that occupation, and in connection with what company?

A. I have been engaged in the manufacture for about 10 years in connection with the company known as the Edison Lamp Company.

3 Q. Has that company been the exclusive manufacturing agent in the United States for incandescent lamps for the complainant during all that time?

A. Yes.

4 Q. What has been your position in that company?

A. My position has been that of general manager and treasurer.

5 Q. Have the Edison incandescent electric lamps manufactured by the Edison Lamp Company been provided with any marks or labels showing the fact that they were patented, and, if so, what has been the character of such marks or labels, and how they long have been used?

A. As early as the middle of July 1882, labels were placed upon our lamps, giving the dates of five patents under the word "Patented," the label being surcharged with the word "Edison" in red letters. About February 1883, another label was used bearing the words "Edison's Patents.". In connection with this latter label a large label was pasted on the heads of packages showings the dates and numbers of the patents under which the Edison Lamp Company was licensed to manufacture lamps.

6 Q. Please read in full on the record the label which you commenced to use as early as the middle of July 1882?

A. It is as follows:

PATENTED.

Jan. 27, 1880. July 20, 1880.
May 4, 1880. Oct. 18, 1881.
Dec. 27, 1881.

This label has the word "Edison" printed in red letters over the dates.

7 Q. Have all the lamps placed upon the market by

the Edison Lamp Company since July 1882, been marked as you have stated?

A. That has been our practice and I believe that every lamp that has been sold has been so marked.

Cross-examination by Gen. Duncan:

8 x-Q. The first marking of the Edison lamps was done in July of 1882?

A. The first record I found indicates that the lamps were marked in July, 1882. My belief is, that some lamps were marked prior to this.

> The witness's statement of his belief is objected to as inadmissable and not responsive.

9 x-Q. Has the Edison Lamp Company ever exposed for sale to the public incandescent lamps which were marked with labels setting forth the dates of the patents, either by attaching such labels to the lamps themselves, or by affixing them to the packages in which the lamps were contained?

A. The Edison Lamp Company have never dealt directly with the public in selling. By contract with the Edison Electric Light Company the sales of the Edison Lamp Company were restricted to sales to the licensees of the Edison Electric Light Company.

10 x-Q. Have any of the different grades of lamps made by the Lamp Company been put on sale in the general market?

A. Lamps have been sold in the general market to parties who specifically state where the lamps would be used.

11 x-Q. Are not some grades of the Edison lamps kept in stock by the electrical supply men for sale to the public generally?

A. Greely & Company of this city have kept a supply of lamps for use with small batteries.

12 x-Q. Where do they get their supply?

A. They have obtained them of the Lamp Company by an arrangement with the Edison Electric Illuminating Company of New York City.

13 x-Q. What is the text of the label which you say your company adopted in 1883, and have used ever since on your lamp packages?

A. I produce one of the labels in present use, which is substantially the label used since 1883, except that when a new edition of labels has been printed the patents have been added to bring the list of patents down to date.

> Complainant's counsel offers in evidence the label produced by the witness, and the same is marked Complainant's Exhibit, Edison Lamp Package Label.

Francis R. Upton.

Commission.

THE PRESIDENT OF THE UNITED STATES OF AMERICA,

To Henry C. Monk, Esq., of Ottawa, Province of Ontario, Dominion of Canada, Greeting:

Know ye, That we, in confidence of your prudence and fidelity, have appointed you Commissioner, and by these presents do give you full power and authority, diligently to examine, upon their corporal oaths or affirmations, before you to be taken, and upon the interrogatories and cross-interrogatories hereunto annexed, William McDougal, of the City of Ottawa, Ontario, Canada, and Desire Girouard, of the City of Montreal, Quebec, Canada, as witnesses on the part of the complainant, in a certain cause now pending undetermined in the Circuit Court of the United States of America, for the Southern District of New York, wherein the Edison Electric Light Company is complainant and the United States Electric Lighting Company is defendant. And we do hereby require you, before whom such testimony may be taken, to reduce the same to writing, and to close it up under your hand and seal, directed to John A. Shields, Clerk of the Circuit Court of the United States for the Southern District of New York, at the City of New York, as soon as may be convenient after the execution of this commission; and that you return the same when executed, as above directed, with the title of the cause endorsed on the envelope of the commission.

Witness the Honorable MELVILLE W. FULLER, Chief-Justice of the Supreme Court of the United States, at the City of New York, this 30th day of July, in the year of our Lord one thousand eight hundred and ninety, and of our Independence the one hundred and fifteenth.

[SEAL.] JOHN A. SHIELDS,
Clerk of the Circuit Court of the United States for the Southern District of New York.

The execution of this commission appears in certain schedules hereunto annexed.

HENRY C. MONK,
Commissioner.

At a Stated Term of the Circuit Court of the United States for the Southern District of New York, held at the Court House, in the Post-office Building, in the City of New York, on the 30th day of July, 1890.

Present—HON. E. HENRY LACOMBE, Circuit Judge.

THE EDISON ELECTRIC LIGHT COMPANY,
Complainant,

AGAINST

THE UNITED STATES ELECTRIC LIGHTING COMPANY,
Defendant.

In Equity.
No. 3445.

On reading and filing the annexed consent of Eaton & Lewis, solicitors for complainant, and of Duncan, Curtis & Page, solicitors for defendant, it is

Ordered, that a commission issue out of this Court to Henry C. Monk, Esq., of Ottawa, Province of Ontario, Dominion of Canada, who is hereby appointed Commissioner to examine William McDougall and Desire Girouard upon oath as witnesses on the part of the complainant in the above-entitled cause, on the interrogatories hereto annexed.

E. HENRY LACOMBE.

CIRCUIT COURT OF THE UNITED STATES,

For the Southern District of New York.

The Edison Electric Light Company, Complainant, against The United States Electric Lighting Company, Defendant.	In Equity. No. 3445.

It is hereby stipulated and agreed that a commission issue out of this Court to Henry C. Monk, Esq., of Ottawa, Province of Ontario, Dominion of Canada, appointing the said Henry C. Monk Commissioner to examine William McDougall and Desire Girouard upon oath as witnesses on the part of the complainant herein on the interrogatories hereto annexed, and that an order to that effect be entered herein, without further notice.

Dated New York, July 28, 1890.

Eaton & Lewis,
Solicitors for Complainant.
Duncan, Curtis & Page,
Solicitors for Defendants.

CIRCUIT COURT OF THE UNITED STATES,

For the Southern District of New York.

The Edison Electric Light Company, Complainant, vs. The United States Electric Lighting Company, Defendant.	In Equity No. 3445.

Interrogatories to be administered to William McDougal, of the City of Ottawa, Ontario, Canada, a witness to be produced, sworn and examined, under and by virtue of the annexed commission, before Henry C. Monk, the Commissioner therein named, in the above entitled cause on the part of the complainant.

First Interrogatory. What is your residence, age, profession, and past and present official position, if any? Are you acquainted with the statute laws of the Dominion of Canada? What has been your experience in interpretating the same?

Second Interrogatory. What statute or other law prevailed in Canada on the 17th day of November, 1879, limiting the duration of Canadian patents to the duration of foreign patents for the same invention?

Please give in your answer a copy of any part or parts of any statute which you may refer to as comprising the law at that time on the subject.

Third Interrogatory. If in your answer to the last interrogatory you shall have pointed out any statue or statutes, state how long that law continued in force, and, if it had been in any wise changed, please state the time and character of the same. During the time since November 17th, 1879, has the law of Canada made the duration of Canadian patents to depend upon the continuance of foreign patents of later date?

FOURTH INTERROGATORY. Assume, if you please, that a patent was granted to Thomas Alva Edison in Canada on the 17th day of November, 1879, and numbered 10,654; and that the said Edison, after the granting of his Canadian patent, to wit, in May, 1880, obtained in the Kingdom of Sweden a patent for the same invention, would the expiration of that Swedish patent, for any cause whatsoever, affect, in your judgment, the legal duration of the Canadian patent mentioned?

FIFTH INTERROGATORY. In any case where the termination of a foreign patent would have or could be made to have an effect upon the duration of a Canadian patent, would that effect result *ipso facto* from the termination of the foreign patent, or would it depend in any way upon judicial or other action or determination to be taken in Canada?

CIRCUIT COURT OF THE UNITED STATES,

FOR THE SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY, Complainant, AGAINST THE UNITED STATES ELECTRIC LIGHTING COMPANY, Defendant.	In Equity, No. 3445.

Interrogatories to be administered to Desire Girouard, of the City of Montreal, Quebec, Canada, a

witness to be produced, sworn and examined under and by virtue of the annexed commission, before Henry C. Monk, the Commissioner, therein named in the above-entitled cause on the part of the complainant.

FIRST INTERROGATORY: What is your residence, age, profession, and past and present official position, if any; are you acquainted with the Statute Laws of the Dominion of Canada; what has been your experience in interpreting the same?

SECOND INTERROGATORY: What statute or other law prevailed in Canada on the 17th day of November, 1879, limiting the duration of Canadian patents to the duration of foreign patents for the same invention? Please give in your answer a copy of any part or parts of any statute which you may refer to as comprising the law at that time on the subject.

THIRD INTERROGATORY: If in your answer to the last interrogatory you shall have pointed out any statute or statutes, state how long that law continued in force, and if it had been in any wise changed please state the time and character of the change. During the time since November 17th, 1879, has the law of Canada made the duration of Canadian patents to depend upon the continuance of foreign patents of later date?

FOURTH INTERROGATORY: Assume, if you please, that a patent was granted to Thomas Alva Edison in Canada on the 17th day of November, 1879, and numbered 10,654, and that the said Edison after the granting of his Canadian patent, to wit, in May, 1880, obtained in the Kingdom of Sweden a patent for the same invention, would the expiration of that Swedish patent, for any cause whatsoever, affect, in your judgment, the legal duration of the Canadian patent mentioned?

FIFTH INTERROGATORY: In any case where the termination of a foreign patent would have, or could be made to have, an effect upon the duration of a Canadian patent would that effect result *ipso facto* from the termination of the foreign patent, or would it depend in any way upon judicial or other action or determination to be taken in Canada?

UNITED STATES CIRCUIT COURT.

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY vs. THE UNITED STATES ELECTRIC LIGHTING CO.	In Equity, No. 3445.

Cross-interrogatories by counsel for defendant, to be administered to William McDougal, a witness in behalf of complainant.

CROSS-INTERROGATORY I. Regarding the matter inquired about in the last paragraph of interrogatory 3, please state whether there has been any judicial determination in Canada to the effect that during the time since November 17th, 1879, the law of Canada has not made the duration of Canadian patents to depend upon the continuance of foreign patents on the same inventions, even when such foreign patents were of later date than the Canadian Patents. If so, please cite the case and state where in the reports it may be found.

CROSS-INTERROGATORY II. If as to the matter inquired about in Interrogatory 4, you shall be of the opinion that the expiration of the Edison Swedish patent named therein would not effect the legal duration of the Edison Canadian patent also named therein, please state whether this question has been determined by any Canadian Court; and, if so, please cite the case and state where in the reports the case can be found.

CROSS-INTERROGATORY III. As to the matter inquired about in Interrogatory 5, please state whether it has been determined by any Canadian Court that the termination of the foreign patent does not *ipso facto* affect the duration of the Canadian patent. If so, please cite the case and state where in the reports it is to be found.

CROSS-INTERROGATORY IV. Section 7 of the Patent Law of Canada of 1872 contains this provision respecting the effect of a foreign patent upon the life of a Canadian patent on the same invention. "Under any circumstances, where a foreign patent may exist, the Canadian patent shall expire at the earliest date at which any foreign patent shall expire."

If while that provision of law was in force a foreign patent had expired under circumstances that would have brought a Canadian patent within the scope of such provision, might not a person sued in a Canadian court for a subsequent infringement of the Canadian patent have made a valid defense by proving the expiration of such foreign patent?

UNITED STATES CIRCUIT COURT.

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT CO. vs. THE U. S. ELECTRIC LIGHTING CO.	In Equity, No. 3445.

Cross-interrogatories by counsel for defendant, to be administered to DESIRE GIROUARD, witness in behalf of complainant:

CROSS-INTERROGATORY I. Regarding the matter inquired about in the last paragraph of Interrogatory 3, please state whether there has been any judicial determination in Canada to the effect that during the time since November 17th, 1879, the law of Canada has not made the duration of Canadian patents to depend upon the continuance of foreign patents on the same inventions even when such foreign patents were of later date than the Canadian patents. If so, please cite the case and state where in the reports it may be found?

Cross-Interrogatory II. If as to the matter inquired about in Interrogatory 4, you shall be of the opinion that the expiration of the Edison Swedish patent named therein would not affect the legal duration of the Edison Canadian patent also named therein, please state whether this question has been determined by any Canadian Court, and, if so, please cite the case and state where in the reports the case can be found?

Cross-Interrogatory III. As to the matter inquired about in Interrogatory 5, please state whether it has been determined by any Canadian Court that the termination of the foreign patent does not *ipso facto* affect the duration of the Canadian patent. If so, please cite the case and state where in the reports it is to be found?

Cross-Interrogatory IV. Section 7 of the Patent Law of Canada, 1872, contains this provision respecting the effect of a foreign patent upon the life of a Canadian patent on the same invention. "Under any circumstances, where a foreign patent exists, the Canadian patent shall expire at the earliest date at which any foreign patent shall expire."

If while that provision of the law was in force a foreign patent had expired under circumstances that would have brought a Canadian patent within the scope of such provision, might not a person sued in the Canadian Court for a subsequent infringement of the Canadian patent have made a valid defense by proving the expiration of such foreign patent.

Depositions of William McDougall and Desire Girouard, the witnesses produced, sworn, and examined the eleventh and fifteenth days of August, in the year one thousand eight hundred and ninety, respectively, at the City of Ottawa, in the province of Ontario, and Dominion of Canada, under and by virtue of a commission, issued out of the Circuit Court of the United States, for the Southern District of New York, in a certain cause therein depending and at issue, wherein the Edison Electric Light Company is complainant, and the United States Electric Lighting Company is defendant.

Deposition of William McDougall, a witness produced, sworn, and examined, the eleventh day of August, in the year of our Lord, one thousand eight hundred and ninety, at the City of Ottawa, in the County of Carleton and Dominion of Canada: under and by virtue of a commission issued out of the Circuit Court of the United States, for the Southern District of New York, in a certain cause therein depending and at issue, wherein the Edison Electric Light Company is complainant, and The United States Electric Lighting Company is defendant as follows:

William McDougall of the City of Ottawa, in the County of Carleton, and Dominion of Canada, barrister-at-law, aged sixty-seven years and upwards, being duly and publicly sworn, pursuant to the directions hereto annexed, and examined on the part of the complainant, doth depose and say as follows:

First. To the first interrogatory he saith:

That he is a lawyer by profession, was born in the year eighteen hundred and twenty-two, was admitted to practice as an attorney in Upper Canada in the year eighteen hundred and forty-seven, was called to the bar in the year eighteen hundred and sixty-two, and appointed a Queen's Counsel in eighteen hundred and eighty-one. That he now resides in Ottawa City, the capital of the Dominion of Canada, and was a member of Parliament, with a short interval from the year eighteen hundred and fifty-eight, to the year eighteen hundred and eighty-two, and during that period held office in three successive cabinets.

First, as Commissioner of Crown Lands.

Second, as Provincial Secretary.

Third, as Minister of Public Works. That he was one of the delegates in the year eighteen hundred and sixty-seven to the London Conference to complete the terms of union of the British North American Colonies, and in his positions as member of Parliament and Minister of the Crown, he assisted actively in framing the Statutes of Canada, including the Patent Act of eighteen hundred and sixty-nine, upon which all subsequent legislation on that subject is based. That his professional practice of late years has been chiefly devoted to Parliamentary, Railway, Patent, and Corporation matters, which necessarily led him to study and interpret the Statutes of Canada.

SECOND. To the second interrogatory he saith:

That the Statute Law in force in Canada on the seventeenth day of November, in the year eighteen hundred and seventy-nine, relating to patents for inventions, foreign and domestic, was the Act of the Dominion Parliament, thirty-fifth Victoria, Chapter twenty-six. That this Act took effect in Canada on the fourteenth of June, one thousand eight hundred and seventy-two, and was not altered or amended until the twenty-fifth of May, eighteen hundred and eighty-three. That the amendment of that year was limited to one section of the Act, viz.; that which gives the inventor or patentee the option of paying the patent fee for terms of five or ten years instead of the full term of fifteen years. That the section of the Act in force in Canada on the seventeenth of November, eighteen hundred and seventy-nine, which related to or limited the duration of Canadian patents to the duration of foreign patents for the same invention was Section seven of the Patent Act already mentioned to wit: Thirty-fifth Victoria, Chapter twenty-six. It is in these

words: "But an inventor shall not be entitled to a "patent for his invention, if a patent therefor in any "other country shall have been in existence in such "country more than twelve months prior to the application for such patent in Canada, and if during such "twelve months any person shall have commenced to "manufacture in Canada the article for which such "patent is afterwards obtained such person shall "continue to have the right to manufacture and sell "such article notwithstanding such patent, and under "any circumstances where a foreign patent exists the "Canadian patent shall expire at the earliest date at "which any foreign patent for the same invention expires."

That he always understood that the expiration of a Canadian patent by reason of the lapse or expiry of a foreign patent for the same invention was limited by this section to patents existing prior to the application for patent in Canada. That he reads the qualifying clause at the end of the section as if the word "then" had been inserted before the word "exists," and the word "such" after the word "any" in that clause. That he cannot believe the Canadian Parliament intended to subject its patentee to deprivation or forfeiture because some foreign country may choose to limit the term of its patents to a shorter period than that which had been granted to him and paid for in Canada. That the Canadian Patent Office, in other words the Canadian Government, has always hitherto acquiesced in the construction he contends for, and that he finds no record of any judicial opinion to the contrary.

THIRD. To the third interrogatory he saith:

That the Statute law in force in Canada on the seventeenth of November, eighteen hundred and seventy-nine, limiting the duration of Canadian patents to the duration of foreign patents for the same invention, remains in force to-day. That the few verbal changes made in the revision of the Statutes in eighteen hundred and eighty-six, do not, in his opinion, affect the duration of Canadian patents in their relation to or dependence upon foreign patents. That the substitution of the word "if" for the word "when" in the last clause of section seven (now section eight of the Revised Statutes) conveys, in his opinion, with greater accuracy the true intent of the Legislature. That the words "under any circumstance" must, he apprehends, be limited by the subject matter—under any of the "circumstances" contemplated by that section is the evident intent. That if a foreign patent for the same invention "exists" when the application is made in Canada, and has not existed more than twelve months, a patent may be granted, but its duration will be limited to the unexpired term or life of any foreign patent so existing for the same invention which shall first expire.

Fourth. To the fourth interrogatory he saith:

That he is of opinion that the expiration of the Swedish patent, under the conditions stated, would have no effect upon the Canadian patent. That every nation or country empowered to enact laws for its own government may annex or impose what conditions it pleases in granting patents. That Sweden may have limited the term or life of its patents to ten years; Canada grants all patents for the term of fifteen years; and that he is not aware that she has ever authorized any foreign country to make or modify her laws or annul her contracts.

Fifth. To the fifth interrogatory he saith:

That in the case supposed (limited as he believed it must be to foreign patents "existing" prior to the Canadian patent) the termination of the foreign patent would *ipso facto* terminate the Canadian patent; but he apprehends that a mere rumor to that effect would not avail; Coke's maxim "*Omnia praesumuntur legitime*, etc," would probably govern the Patent Office, as well as the Courts of law. In other words, the *fact* of termination must be proved.

First. To the first cross-interrogatory he saith:

On inquiry he finds that no Canadian Court, since the seventeenth day of November, eighteen hundred and seventy-nine, has rendered judgment to the effect suggested. That the officials of the Patent Office at Ottawa are unaware of any judicial determination of that kind.

Second. To the second cross-interrogatory he saith:

Being of the opinion that the expiration of the Edison Swedish Patent under the circumstances stated had no effect upon the duration of the Edison Patent in Canada, he was not surprised to learn at the Patent Office in Ottawa that no judicial determination to the contrary had come to the knowledge of that department.

Third. To the third cross-interrogatory he saith:

That he is not aware of any decision by any Canadian Court that the termination of a foreign patent for the same invention will *ipso facto* affect the duration of the Canadian Patent; but is of the opinion, as stated in answer to interrogatory number five, that a foreign patent "existing" at the time of the grant of the Canadian Patent will be terminated *ipso facto* by the termination of such foreign patent in existence previous to the grant of the Canadian patent.

Fourth. To the fourth cross-interrogatory he saith:

That the provision referred to as Section Seven of the Patent Act of eighteen hundred and seventy-two, is incorrectly quoted; "where a foreign patent exists" is the language of the Act; "where a foreign patent *may* exist," might in the opinion of the Court of law require a different construction. The words "shall expire at the earliest date at which any foreign patent *shall* expire" may be held to convey a different meaning from the words of the Act, viz., "shall expire at the earliest at which any foreign patent *for the same invention expires.*"

That since eighteen hundred and eighty-six the Revised Statutes of Canada govern the Courts as well as the Patent Office, upon all matters thereafter arising.

The word "if" was substituted for the word "where," for the purpose, as he believes, of expressing more clearly the intent of the Legislature to admit the forfeiture or termination of the grant to then "existing foreign patents."

That as in the case supposed in the last clause of the fourth cross-interrogatory could only arise in respect of foreign patents previously existing, he answers the question with that postulate, in the affirmative.

WM. McDOUGALL.

Examination taken, reduced to writing and by the witness subscribed and sworn to this eleventh day of August, A. D. 1890.

HENRY C. MONK,
Commissioner.

DOMINION OF CANADA,
Province of Ontario,
County of Carleton.

I, Henry Carleton Monk, do certify that William McDougall, the witness, personally appeared before me the eleventh day of August, eighteen hundred and ninety, at five o'clock in the afternoon, at the City of Ottawa, in the Province of Ontario, in the Dominion of Canada, and after being sworn to testify the truth, the whole truth and nothing but the truth, did depose to the matters contained in the foregoing deposition, and did in my presence subscribe the same. And I further certify that I have subscribed my name to each half sheet thereof.

HENRY C. MONK,
Commissioner.

Deposition of DESIRE GIROUARD, a witness produced, sworn and examined, the fifteenth day of August, in the year of our Lord, one thousand eight hundred and ninety, at the City of Ottawa, in the County of Carleton and Dominion of Canada; under and by virtue of a commission issued out of the Circuit Court of the United States, for the Southern District of New York; in a certain cause therein depending and at issue, wherein the Edison Electric Light Company is complainant and the United States Electric Lighting Company is defendant, as follows:

Desire Girouard, of the City of Montreal, in the province of Quebec and Dominion of Canada, a member of the Bar of the province of Quebec, aged fifty-four years and upwards, being duly and publicly sworn, pursuant to the directions hereto annexed, and examined on the part of the complainant, doth depose and say as follows:

FIRST. To the first interrogatory he saith:

My home is at "Quatre Vents," Dorval, near Montreal, but I reside during the winter partly in the City of Montreal, and partly in the City of Ottawa.

My age is fifty-four years, on the 7th July last. I have been a member of the Bar of the province of Quebec since October, 1860, and from that date have been employed in many important commercial cases before the Courts in the City of Montreal, and also before the Supreme Court of Canada, in the City of Ottawa, and have had considerable practice in the construction and interpretation of Canadian Statutes, and especially Railway, Patent and Customs Statutes.

I have on various occasions contributed articles and written books upon some of these statutes; among others, the Bills of Exchange and Promissory Note Act of 1849; the Insolvent Act, of 1864, etc.

I am a D. C. L. (Doctor of Laws) of Magill University, and a Queen's Counsel since 1876.

I represent the County of Jacques Cartier in the House of Commons of Canada since the year 1878, and as a Member of Parliament have had to become acquainted with the statute laws of the Dominion of Canada.

I have been chairman of the Judicial Committee of the House of Commons, known as the Committee of Privileges and Elections, during the last and present Parliaments.

SECOND. To the second interrogatory he saith:

On the 17th of November, 1879, the law relating to the duration of Canadian Patents, as influenced by foreign patents for the same invention, was section seven of an act passed by the Parliament of Canada on the 14th June, 1872, and cited as "The Patent Act of 1872."

This section 7, which is the only one of the Statute referring to foreign patents as affecting Canadian patents, reads as follows: "But an inventor shall not be entitled to a patent for his invention; if a patent therefor in any other country shall have been in existence in such country more than twelve months prior to the application for such patent in Canada, and if during such twelve months any person shall have commenced to manufacture in Canada the article for which such patent is afterwards obtained, such person shall continue to have the right to manufacture and sell such article, notwithstanding such patent; and under any circumstances where a foreign patent exists, the Canadian patent shall expire at the "earliest date at which any foreign patent for the sameinvention expires."

This section, which comprises the law in force in Canada on the 17th Nov., 1879, contemplates, in my opinion, only foreign patents prior to the application for the patent in Canada, and not patents which existed abroad after said application for such patent in Canada, and the latter part thereof which reads as follows: "And under any circumstances, where a foreign patents exists, the Canadian patent shall expire at the earliest date at which any foreign patent for the same invention expires," I hold to refer only to a foreign patent existing prior to the application for a Canadian patent and not to a foreign patent existing after the granting of the Canadian patent, nor to a foreign patent granted before the granting of the Canadian patent but after the application for the latter. My reasons for giving this construction are the following:

1. In the first place, the whole clause must be read together. The first portion of it undoubtedly refers to patents prior to the Canadian patent; and the words "and under any circumstances," which precede the latter part of the section, are in my mind a clear indication that the Legislature intended to speak of the same class of subjects, viz.: foreign patents in existence prior to the application for the Canadian patent, whether in existence before or after the twelve months referred to in the first part of the section.

For this reason, the words, "and under any circumstances where a foreign patent exists," etc., have a plain meaning and are intended to refer not only to foreign patents in existence more than twelve months prior to the application for a Canadian patent, but also to foreign patents in existence after said twelve months but prior to the application for said patent in Canada.

2. In the second place, I take it for granted that the following is an axiom in the construction of the statutes. Where a particular class of things is spoken of, and general words follows, the first class mentioned is to be taken as the most comprehensive, and the general words treated as referring to matters *ejusdem generis* with such class (Broom's Legal Maxims, 5th Am. Ed. p. 436).

Therefore the latter part of the section refers only to foreign patents obtained before the application for the Canadian patent.

3. In the third place, another well known rule in the construction of a statute is that a passage will be best interpreted by reference to that which precedes and follows it; "*ex antecedentibus et consequentibus fit optima interpretatio*" (Broom, *Ibid.*, pp. 386 and 397).

That passage of Section 7 of the Patent Act of 1872 which (declares that the Canadian patent shall expire at the earliest date at which any foreign patent for the same invention expires) is immediately preceded by one referring only to foreign patents existing previous to the application for the Canadian patent, and there is nothing following in the section or in the statute, which refers to foreign patents in any way whatever.

The whole clause, therefore, relates to the same subject matter, namely, foreign patents existing prior to the application for the Canadian patent.

4. In the fourth place. To declare a Canadian patent forfeited or expired before the ordinary lapse of time fixed by our Canadian statute, namely fifteen years, is to impose a penalty or forfeiture upon the patentee, and I take it for granted that it is a good principle of law prevailing everywhere, that a penalty or forfeiture cannot be imposed otherwise than by the clear words of the statute. (Broom, *Ibid.*, p. 382; Bedarride, Brevets d'Invention, p. 347.)

5. In the fifth place. I take it to be a good rule in the construction of a patent statute under the full application of the principle, "*ut res magis valeat quam pereat*," that patents for inventions are, if practicable, to be so interpreted as to uphold and not to destroy the right of the inventor. (Bump's Patents, p. 36.)

6. In the sixth place. There is a rule laid down by Lord Bacon, which has since been accepted as a maxim of law, that in doubtful cases the construction of a statute must be consonant with equity. It seems to me that the wording of a statute would require to be very clear, in order to deprive a man of his property. Therefore, the title by which the patent for an invention has been obtained, should not be overthrown merely on account of doubts and objections which are capable of a just and reasonable solution in favor of its validity.

7. The putting of any other construction upon section 7 of the statute, would defeat the very object of the Canadian Patent Act, for, if correct, its effect would be to destroy the value of any patent, whose duration or existence would depend upon the subsequent act of a foreign country; and assignments of patents would become almost valueless.

THIRD. To the third interrogatory he saith:

Section 7 of the Patent Act of 1872, quoted at length in the preceding answer, has remained in force ever since the 14th June, 1872, and still constitutes the law of Canada to-day.

Section 17 of the same Act of 1872 provides for the duration of a Canadian patent independently of any foreign patent, and has no bearing upon the question. It reads as follows:

"Patents of inventions issued by the Patent Office "shall be valid for a period of five, ten or fifteen years, "at the option of the applicant; but at or before the "expiration of the said five or ten years, the holder "thereof may obtain an extension of the patent for "another period of five years, and after those second five "years, may again obtain a further extension for another "period of five years, not in any case to exceed a total "period of fifteen years in all; and the instrument "delivered by the Patent Office for such extension of "time, shall be in the form which may be from time to "time adopted, to be attached with reference to the "patent, and under the signature of the Commissioner, "or of any other member of the Privy Council, in case "of absence of the Commissioner."

On the 25th May, 1883, the Parliament of Canada, by an amendment to section 17 of said patent act, gave the patentee the option of paying the patent fee by different periods of five or ten years, instead of making one payment for the full term of fifteen years, and at the same time declared, in a most emphatic manner, that the term of duration of every patent of invention issued in Canada had been and should continue to be of fifteen years.

In introducing this admendment in the House of Commons, the Honorable Mr. Pope, at the time Minister of Agriculture, remarked that its object was to come to the relief of American inventors who, having obtained Canadian patents prior to their American patents, exercise the aforesaid option.

The remarks of the Minister are to be found in the Commons Hansard, 1883.

The amendment was thought advisable in order to remove doubts which had arisen in consequence of other parts of the Statute of 1872 (more particularly section 17) qualifying these different periods of ten and fifteen years as "an extension of the patent."

This amendment has not the least effect upon section 7 of the Patent Act of 1872, but it shows, nevertheless, that the policy of the Canadian Government, and Parliament, has been to foster and encourage patents for invention, and their duration.

In the year 1886 the statutes of Canada were revised, and under a proclamation of the Governor-General in Council, came into force on the 1st March, 1887.

The patent act will be found to be the 49 Vict., Chap. 61, and the text of section 7, of the Act of 1872, is reproduced almost *verbatim* in section 8 of the Revised Statutes.

By *verbatim* I mean that the few verbal changes made in the revision cannot affect the text and meaning of the original section.

The revised section reads as follows:

"No inventor shall be entitled to a patent for his "invention if a patent therefor in any other country "has been in existence in such country for more than "twelve months prior to the application for such patent "in Canada, and if, during such twelve months, any "person has commenced to manufacture in Canada the "invention for which such patent is afterwards obtained, "such person shall continue to have the right to manu- "facture and sell such articles notwithstanding such "patent; and under any circumstances, if a foreign "patent exists, the Canadian patent shall expire at the "earliest date at which any foreign patent for the same "invention expires."

Since the 17th November, 1879, no law has been passed in Canada to make the duration of Canadian patents depend upon foreign patents for the same invention, when the latter are of later date than the Canadian patent. In my opinion, no Canadian statute can be found to refer, directly or indirectly, to foreign patents existing subsequently

to the application for a Canadian patent, and in this respect, I believe the Canadian patents law agrees with that of nearly all civilized nations of the day.

Fourth: To the fourth interrogatory he saith:

Assuming the granting of the Sweden patent in the year 1880, as stated in this interrogatory, the expiration of that Swedish patent by ordinary lapse of the term or by non-payment of the patent fees, or by forfeiture, or by any cause or reason whatsoever, cannot, in my judgment, affect the legal duration of the Canadian patent mentioned in said interrogatory, for the reasons already submitted in my answer to the second interrogatory.

Fifth: To the fifth interrogatory he saith:

In the case supposed, where the termination of a foreign patent would have or could be made to have an effect upon the duration of a Canadian patent (and I take it for granted that this could only happen when the foreign patent was "in existence" prior to the application for the Canadian patent) such effect would result *ipso facto* from the termination of the foreign patent; and I fail to see the necessity of any action or judicial determination upon the point in Canada.

First. To the first cross-interrogatory, he saith:

The effect upon a Canadian patent of a foreign patent obtained either previous or subsequent to said Canadian patent, has never, to my knowledge, received any judicial determination in Canada. And more particulatly with regard to the matter inquired into in the last paragraph of interrogatory 3, I am not aware that there has been any judicial decision in Canada, to the effect that at any time since the said 17th November, 1879, the law has or has not, one way or the other, made the duration of Canadian patents to depend upon the continuation of foreign patents for the same invention, when the latter are of subsequent date to the Canadian patents.

SECOND. To the second cross-interrogatory, he saith: The question referred to in this cross-interrogatory has not been determined by any Canadian Court.

THIRD. To the third cross-interrogatory he saith: I do not know of the existence of any judicial decision of any Canadian Court to the effect that the termination of any foreign patent does or does not affect, one way or the other, the termination of the Canadian patent.

FOURTH. To the fourth cross-interrogatory he saith: The test of Section 7 of the Patent Act of Canada, 1872, is not produced *verbatim*, but I presume that for the purposes of the question the variance is immaterial. I am of the opinion that where a foreign patent has expired under circumstances which would have brought a Canadian patent within the scope of the provision contained in the latter part of said Section 7, a person sued in the Canadian Court for a subsequent infringment of the Canadian patent would make a valid defense by alleging and proving the expiration of such foreign patent.

D. GIROUARD.

Examination taken, reduced to writing, and by the witness subscribed and sworn to this 15th day of August, A. D. 1890.

HENRY C. MONK,
Commissioner.

PROVINCE OF ONTARIO,
County of Carleton.

I, HENRY CARLETON MONK, do certify that Desire Girouard, the witness, personally appeared before me, on the fifteenth day of August, eighteen hundred and ninety, at seven o'clock in the afternoon, at the City of Ottawa, in the Province of Ontario, in the Dominion of Canada; and after being sworn to testify, the truth, the whole truth, and nothing but the truth, did depose to the matters contained in the foregoing deposition, and did, in my presence, subscribe the same. And I further certify that I have subscribed my name to each half sheet thereof.

HENRY C. MONK,
Commissioner.

NEW YORK, September 25, 1890.

Met pursuant to adjournment.

Present—R. N. DYER, for complainant, and S. A. DUNCAN, for defendant.

RICHARD N. DYER, being duly sworn as a witness on behalf of complainant, testifies as follows:

I have had charge of the taking of complainant's testimony in this case and cross-examined the defendant's witness, Charles R. Cross. During that cross-examination I called Prof. Cross' attention to a correspondence carried on in May and June, 1881, between himself and Mr. F. R. Betts, at that time counsel for the complainant, and between himself and Major S. B. Eaton, at that time vice-president of the complainant company, relating in part to the patent in suit. At that time I knew of the existence of no other letters or papers relating to or forming part of the correspondence; neither did Prof. Cross, as appears by his answer to 86 x-Q. I had, prior to the cross-examination, had a search made among the papers of Mr. Betts and Major Eaton, and in the files of the complainant. Some time after the closing of Prof. Cross' cross-examination, I observed, in reading the Eaton-Cross letter of June 16, 1881, that a letter from Prof. Cross to Mr. Betts, dated June 11th, was referred to. I again requested Mr. Betts to search for further letters from Prof. Cross, and particularly for a letter of this date. As a result of that search, he sent me a letter signed by Prof. Cross, and dated June 11, 1881, addressed to himself, and a letter signed by Prof. Cross and addressed to Major Eaton, dated June 23, 1881, the originals of which letters I now produce. Mr. Betts sent me these two letters April 2d, 1890, and within a week or two after that date I told Mr. Curtis, one of defendant's counsel, of the discovery of these letters and handed him copies of them.

Complainant's counsel offers the two letters referred to in evidence, and the same are marked respectively "Complainant's Exhibit Cross-Betts Letter of June 11, 1881," and "Complainant's Exhibit Cross-Eaton Letter of June 23, 1881."

Defendant's counsel, so far as the same can be done without prejudice to the objection hereinafter stated, waives proof of the genuineness of the two letters of Prof. Cross of June 11 and June 23, 1881, offered in evidence, and admits that such letters were written and mailed by Prof. Cross on the dates named and were received in due course of mail by the persons to whom they are addressed, subject to the correction of errors, if the fact should be found to be otherwise, and it is stipulated that copies of the two letters may be substituted for the original letters in the record, subject to the correction of errors.

Defendant's counsel, however, objects to the introduction of the foregoing letters, on the ground, first, of immateriality, and secondly, on the ground that they are not offered until after the witness Cross has been withdrawn. The letters being offered, manifestly, to contradict or to qualify statements made by the witness in his direct examination, they cannot in any event be admissible except as the reputed writer be given the opportunity to deny or to explain them. No opportunity for doing this now exists. Defendant cannot properly be put to the expense of recalling the witness from the distant city where he resides for this purpose.

Complainant's counsel states that if the defendant desires the opportunity to examine the witness Cross with reference to the said letters, he (complainant's counsel) will consent that the same may be done at any time within ten days from this date.

Cross-examination waived.

RICHARD N. DYER.

UNITED STATES CIRCUIT COURT,

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY AGAINST THE UNITED STATES ELECTRIC LIGHTING COMPANY.	In Equity. No. 3445.

NEW YORK, November 24th, 1890.

Present — MESSRS. SEWARD, LOWREY, EATON and DYER, of counsel for the complainant.

No appearance on behalf of defendant.

Plaintiff offers in evidence the notice of hearing of November 24, 1890, with admission of service, which is marked "Plaintiff's Exhibit Notice of November 24, 1890."

Plaintiff also offers in evidence letter from Thomas B. Kerr to Messrs. Eaton & Lewis, of same date, which is marked "Plaintiff's Exhibit Kerr Letter, November 24, 1890."

The further hearing adjourned until Tuesday, November 25, 1890, at 11:30 A. M.

Plaintiff's Exhibit "Plaintiff's Notice of Nov. 24, 1890," S. M. H., Exr.

UNITED STATES CIRCUIT COURT,

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY VS. THE UNITED STATES ELECTRIC LIGHTING COMPANY.	In Equity. No. 3445.

To MESSRS. KERR & CURTIS,
Solicitors for Defendant:

GENTLEMEN—Take notice, that at 2 P. M. on this day a session will be held before the Examiner, S. M. Hitchcock, Esq., at the office of C. A. Seward, Esq., No. 29 Nassau street, this city, at which you are invited to attend.

EATON & LEWIS,
Solicitors for Complainant.

New York, November 24, 1890.

Plaintiff's Exhibit "Kerr's Letter of November 24, 1890." S. M. H., Exr.

Law Offices of
KERR & CURTIS,
THOMAS B. KERR,
LEONARD E. CURTIS.

EQUITABLE BUILDING,
120 Broadway, New York.

NEW YORK, November 24, 1890.

MESS. EATON & LEWIS, New York.

GENTLEMEN—I am in receipt of a notice to take testimony at 2 o'clock to-day in the Edison Electric Company vs. The United States Electric Lighting Company, No. 3445, said notice being left here at 1:20 o'clock P. M. Neither Mr. Curtis, who has special charge of this case, nor Gen. Duncan, who has been acting with him as counsel, is at his office to-day. I therefore object to the notice as unreasonable, and hereby notify you that proper steps will be taken to protect the defendant against the effect of anything you do under it to-day.

Yours truly,
THOMAS B. KERR.

UNITED STATES CIRCUIT COURT,

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY

AGAINST

THE UNITED STATES ELECTRIC LIGHTING COMPANY.

No. 3445.

NEW YORK, Nov. 25, 1890.

Met pursuant to adjournment.

Present—MESSRS. SEWARD and LOWREY, of counsel for complainant; MR. S. A. DUNCAN, of counsel for defendant.

The Examiner states that he has here in his possession the papers sealed by him on November 15, 1890, bearing the endorsement, "Deposited by Grosvenor Lowrey, to be opened only under order of the Court," and bearing the following memorandum signed by Judge LACOMBE: "The Examiner will open. In case of objection to any exhibition of any paper, he will certify objection and paper into Court."

The Examiner further states that this sealed package was handed to him yesterday morning by Judge LACOMBE.

RICHARD N. DYER, called on behalf of the complainant, having been previously sworn, is examined as follows:

BY MR. LOWREY:

1 Q. Referring to the parcel of papers now in possession of the Examiner, will you state for the informa-

tion of the Court what that parcel contains and to what, in general, the papers relate?

A. These papers relate to an application for a patent for Improvements in Incandescent Electric Lamps, filed in the Patent Office by Thomas A. Edison, December 15, 1880, as a division of, and continuation of, an earlier application for patent filed by Mr. Edison upon the same subject, such earlier application having been filed December 11, 1879.

2 Q. Do the contents of that box relate solely and only to the divisional application of December 15, 1880?

A. They contain only the papers of that application, but, of course, the divisional application relates back to the original application filed December 11, 1879, to which I have before referred, and, as I have before stated, this divisional application forms a continuation of the original application.

3 Q. Is there anything in that box which does not relate and which is not founded upon the divisional application?

A. No, sir.

4 Q. Is the divisional application still pending as a continuing application for a patent?

A. It is.

5 Q. Are you able to say without opening the box, by aid of any memorandum which you have, what papers are contained in that box?

A. I am.

6 Q. Please name them and enumerate them?

A. The papers are as follows:

A retained copy of the specification and claims forming part of the divisional application as filed. This copy bears various pencil memoranda which are probably not on the original specification in the Patent Office, but have been made since that was filed, indicating changes for subsequent amendments. These pencil memoranda were made by the solicitor in charge of the case from time to time. Some of these memoranda were made before I received the papers in August, 1882, and some after; but none, as I recollect it, were

made within the last two or three years. Attached to this copy of the specification is a copy of a letter transmitted to the Commissioner of Patents with the application. The signature to the letter is omitted. Then follows the correspondence between the Patent Office and the solicitor of Mr. Edison in the application, this correspondence being composed of at least twenty-eight separate papers, these being letters from the Commissioner of Patents raising various objections to the granting of the patent, and replies thereto by the attorney for the applicant at the time, in the form of briefs, arguments and amendments. The box also contains a retained copy of the drawing accompanying the divisional application.

7 Q. I call your attention to the notice to produce by the defendants herein, printed in Vol. III. of defendant's proofs, page 2050A, as follows:

"Defendant's counsel calls upon the complainant "through its counsel here present, to produce for "examination by the defendant's counsel and for "use in evidence in this case if defendant be so "advised, a copy of a specification, claims and "drawings, forming a part of the divisional application for Letters Patent of the United States "filed in the Patent Office by Thomas A. Edison, "December 15, 1880, under the serial number 264, "in the serial enumeration of Edison's applications; the said application as appears by defendant's Exhibit File Wrapper and Contents, Edison "paper carbon application, being a division of the "said so-called paper carbon application filed by "Edison December 11, 1879."

"And defendant's counsel also in like manner, "and for like purpose, calls upon the complainant to produce copies of any and all the correspondence that has passed between the Patent "Office and the said Edison or the complainant, "or his or its attorneys, in relation to the said "divisional application of December 15, 1880, in-

"cluding any and all amendments of said applica-
"tion that may have been made."

I also call your attention to the subpœna *duces tecum* heretofore served on Mr. Hastings, secretary of the complainant, as follows:

"The President of the United States of America
"to FRANK S. HASTINGS, GREETING:

"We command you, that all business and excuses being laid aside, you appear and attend before Samuel M. Hitchcock, one of the Examiners of the Circuit Court of the United States for the Southern District of New York, at the offices of Duncan & Page, at 120 Broadway, in the City of New York, on the thirtieth day of June, 1890, at two o'clock in the afternoon, to testify and give evidence in a certain suit in equity now pending undetermined in the Circuit Court of the United States for the Southern District of New York, between the Edison Electric Light Company, complainant, and The United States Electric Lighting Company, defendant, on the part of the said defendant, and that you bring with you and produce at the time and place aforesaid, any copy, whether certified or uncertified, that you as secretary of the Edison Electric Light Company now have in your possession, or custody, or under your control, or which the said company or any officer, attorney, solicitor or agent of said company, has in its or his possession or custody, or under its or his control, of the specification and claims, and of the drawing, which formed a part of a certain application for letters patent relative to incandescent electric lamps filed in the Patent Office of the United States by Thomas A. Edison, on or about the 15th day of December, 1880, under the serial number, in the special series of Edison applications of No. 264, the same being a divisional application divided

"off from an earlier application (Edison's serial number thereof being 187), filed by the said Edison on or about December 11, 1879; and also the original and copies, whether certified or uncertified, now in your possession or custody or under the control of the said company or of any of its officers, attorneys, solicitors, and agents of any and all correspondence that has passed between the Patent Office and the said Edison, or the said company, or his or its attorney or agents, in relation to the said application, including all amendments of the said application that may have been made from time to time, and all other deeds, evidences and writings, which you have in your custody or power, concerning the premises. And for a failure to attend, you will be deemed guilty of a contempt of Court, and liable to pay all loss and damages sustained thereby to the party aggrieved, and forfeit two hundred and fifty dollars in addition thereto.

"Witness, the Hon. MELVILLE W. FULLER, Chief-Justice of the Supreme Court of the United States, at the City of New York, the 3d day of June, 1890."

And ask you to say whether the descriptions in this notice to produce and the subpœna *duces tecum* cover by their description the papers contained in the box now in the Examiner's hands, and whether that box contains any papers not mentioned in those last named papers—the notice to produce and subpœna *duces tecum*?

A. The description does cover the papers contained in the box now in the hands of the Examiner, and that box contains only those papers and no others, with, I think, one exception; in addition to the correspondence between the Patent Office and the attorney for the applicant which is called for by the description contained in the notice and subpœna, the box also contains a letter from Z. F. Wilber, at that time the attorney in the application, addressed to myself, and relating in part to this divisional application. With this single exception, the papers are those called for by the description in the notice and subpœna and all of them, and none other.

8 Q. I will ask you to look at the papers which I now hand you, purporting to be notice of motion, with an affidavit made by Leonard E. Curtis attached, and sworn to on the 10th day of March, 1890, and ask you if you will identify those papers and say whether they are what they purport to be—copies of the notice of motion, etc.?

A. I recognize these papers as copies of the original notice of motion, with accompanying affidavit, this being, as I recollect it, the first step taken by the defendant toward securing the production and inspection of the papers now in the hands of the Examiner.

> Complainant's counsel offers the papers referred to in evidence, and the same are marked "Complainant's Exhibit First Notice of Motion to Produce, March 10, 1890."

9 Q. Was any affidavit made and used upon that hearing on behalf of the defendant; if so, by whom, and will you produce copy of the affidavit to be marked in evidence?

A. An affidavit was made by myself, sworn to on the 27th of March, 1890, and was filed by counsel for the complainant at the time of the argument. I have a copy of that affidavit now in my hand.

> Complainant's counsel offers the paper in evidence, and the same is marked "Complainant's Exhibit Dyer Affidavit, March 27, 1890."

10 Q. Please furnish, if you have it, copy of the order of the Court determining that motion?

A. I now do so.

> Mr. Lowrey: It is an order purporting to be entered on the 8th day of April, 1890, and signed by Hon. E. Henry Lacombe, and I offer it in evidence; the same is marked "Complainant's Exhibit Order of Court, April 8, 1890."

11 Q. Was that motion renewed at any time?

A. It was renewed by notice served September 9, 1890, for hearing on September 12th, and on September 10, 1890, the notice of motion was amended. I have a copy of the notice of September 9th renewing the motion, together with the attached affidavit, and also a copy of the amended notice served September 10, 1890.

> Complainant's counsel offers the papers above referred to in evidence, and the same are marked respectively, "Complainant's Exhibit Renewal of Motion of September 9, 1890," and "Complainant's Exhibit Amended Notice of Motion of September 10, 1890."

12 Q. Was any order entered upon the determination of that motion?

A. An order was entered under date of November 5, 1800, signed by the Hon. E. Henry Lacombe, Circuit Judge, a copy of which I now produce.

> Complainant's counsel offers in evidence the paper above referred to, and the same is marked "Complainant's Exhibit Order of Court, November 5, 1890."

13 Q. Please furnish, if you can, to the Examiner, to be marked, the opinion rendered by Lacombe, J., in determining the last named motion?

A. I do so; the opinion is dated October 18, 1890.

> Complainant's counsel offers the paper in evidence, and the same is marked "Complainant's Exhibit Opinion of Lacombe, J., October 18, 1890."

14 Q. I call your attention to what purports to be a notice signed by Kerr & Curtis, addressed to Jacob Herrick and F. S. Hastings, without date. I ask you to state whether, of your own knowledge, that notice was served upon those gentlemen, and whether it

already appears in the record, and if they appeared in obedience to it ?

A. I was present at the hearing in this case on November 15, 1890, at the office of Kerr & Curtis, when proof was made of the facts stated in your question. It is shown at page 2749 of the printed record.

Complainant's counsel offers the notice above referred to in evidence, and asks that it be repeated here for convenience. It is marked "Complainant's Exhibit Defendant's Notice to Herrick and Hastings to appear November 15, 1890," and is as follows:

"UNITED STATES CIRCUIT COURT,

"SOUTHERN DISTRICT OF NEW YORK.

"THE EDISON ELECTRIC LIGHT COMPANY
"vs.
"THE UNITED STATES ELECTRIC LIGHTING COMPANY.
In Equity. No. 3445.

"Please take notice, that the Examiner in the above-"entitled suit will be in attendance at our office in the "Equitable Building, No. 120 Broadway, New York, "on Saturday next, November 15, 1890, at 10 o'clock "in the forenoon, for the purpose of enabling you to "comply, if you be so advised, with the order of the "Court made and filed November 5, 1890, of which "copy has heretofore been served upon you, in regard "to the production of certain papers referred to in "said order.

"Very respectfully,
"KERR & CURTIS,
"Solicitors for Defendant.

"TO MESSRS. JACOB H. HERRICK AND F. S. HASTINGS."

15 Q. I now call your attention to notice of motion printed at page 2762 of the Record, which is as follows:

"Defendant's counsel gives notice that he will "move under the order of November 5th, 1890, on "Friday next, the 21st, at 11 o'clock in the fore-"noon, or as soon thereafter as counsel can be "heard, before the United States Circuit Court, at "the Court House, in the City of New York, for "the punishment of this witness for contempt in "failing to obey the aforesaid order."

and also the notice of motion at page 2755, and state who were the witnesses referred to in those notices?

A. The witnesses were Mr. Hastings, the secretary of the complainant, and Mr. Herrick, the president of the complainant company.

Complainant's counsel offers in evidence the two notices referred to, the one already quoted being marked "Complainant's Exhibit Notice of Motion to Punish Herrick for Contempt;" and the other marked "Complainant's Exhibit Notice of Motion to Punish Hastings for Contempt," being as follows:

"Defendant's counsel gives notice that on Fri-"day next, the 21st inst., at 11 o'clock in the fore-"noon, or as soon thereafter as counsel can be "heard, he will move before the United States "Circuit Court, at the Court House in the City of "New York, for the punishment of Frank S. "Hastings for contempt for his failure to obey the "order of the Court made and filed on the 5th day "of November, 1890."

16 Q. Did those motions come to a hearing; if so, when ?

A. They did, before HON. E. HENRY LACOMBE, Circuit Judge, on Friday last, November 21, 1890.

17 Q. Do you know whether that motion has been decided?

A. I am informed that it has been, and I am shown this morning what purports to be a copy of Judge LACOMBE's decision, purporting to have been filed November 24, 1890, which I now produce.

Complainant's counsel offers in evidence the paper, which is marked "Complainant's Exhibit. Judge Lacombe's Opinion, November 24, 1890."

MR. LOWREY: Complainant's counsel, referring to the record which has been made this morning, and especially to the entry made by the Examiner in relation to the papers now in the custody of the Examiner, asks counsel for the defendant what, if any, claim or demand he now makes in respect to said papers or any of them, and requests that he will state the same upon the record, so as to facilitate the determination of the matter heretofore in contention before the Court.

MR. DUNCAN: In reply, defendant's counsel states that without waiving his objection to the irregularity of this present proceeding, defendant claims and demands in accordance with the language of the renewed motion of September 9th, as amended September 10th, that the complainants produce, for the examination of defendant's counsel, and for use as evidence herein, if defendant be so advised, the full text of the divisional application made by Thomas A. Edison, December 15, 1880, and of all correspondence had in relation thereto between the Patent Office and the said Edison or the complainant herein, or the attorney or attorneys of the said Edison or the said corporation complainant; it being the understanding of defendant's counsel that it was the intention of his Honor Judge LACOMBE, as evidenced by the opinion filed October 18, 1890, to give defendant inspection of said papers.

Complainant's counsel inquires of defendant's counsel, in view of the direction given by the Court by endorsement upon the papers to the Examiner, and the note previously made by the Examiner, whether he now demands from the Examiner, who is in possession, the examination of the papers for the purposes named in his motion.

MR. DUNCAN: If the papers are opened, I propose to make a demand in reference to the same.

THE EXAMINER states that he has now opened the box containing the papers which are in his possession.

Defendant's counsel inquires of the Examiner if he finds among the papers a copy of the specification and claims, together with the drawing accompanying the same, constituting a part of the application made by Thomas A. Edison for Letters Patent of the United States, on the 15th of December, 1880?

THE EXAMINER: I have papers here which purport to be the specification and claims, and the drawing accompanying the same.

Defendant's counsel asks that the Examiner will permit him to take and inspect the said papers.

MR. LOWREY: Counsel for complainant object to the allowance of this examination at this time.

MR. SEWARD: I ask defendant's counsel if he has any objections to stating whether he intends to ask for the production seriatum of the other papers enumerated by Mr. Dyer as being contained with the box in the hands of the Examiner, or whether the notices to produce and the *subpœna duces tecum* are fully filled by the production of the specification, claims and drawings above referred to.

MR. DUNCAN: In reply, defendant's counsel states that in calling for the two papers named, to wit, the specification and claims, and the drawing constituting a part of the application of December 15, 1880, which papers counsel regards as constituting in substance one document, he considers that he is following the suggestion made orally by his Honor Judge LACOMBE at the recent argument of the motion to punish for contempt, said suggestion being, as counsel recalls, to the effect that a practicable course to pursue would be for defendant's counsel when the papers shall be opened by the Examiner, to call for some one of the documents, and in case the exhibition of such document was objected to by complainant's counsel, to request the Examiner to certify the record to the Court for its judgment as to whether such exhibition should be had.

In regard to the other papers alleged to be in the box now in the hands of the Examiner, defendant's counsel states that he sees no present reason for raising an issue in regard to their exhibition so long as the issue in regard to the particular documents designated remains undecided. However, to prevent all misapprehension, defendant's counsel would state that he does not consider that the production of the single document, made up of the specification, claims and drawing, as in any sense a compliance with the demand heretofore made upon complainant and complainant's counsel for the production of all documents connected with this application of December 15, 1880, nor a compliance with the subpoena which has been served upon Messrs. Herrick and Hastings in regard to the production of the said documents.

Mr. Seward: Counsel for complainant says that the only object is to save time and to get the question relating to the right of the defendants in respect to the contents of the said box upon the grounds and for the purposes stated in the notices to produce, and upon the record here before the Court, as one single question, and to save the necessity of placing an objection upon the record, and applying to the Court *seriatum*, as each paper contained in the said box may be called for, and would suggest to the counsel for the defendant that it would accelerate the matter if the counsel would now call at once for all the contents of the box, as enumerated by Mr. Dyer, and for the purposes suggested by the counsel, so that one objection on the part of the complainant would bring the question as to the whole contents of the box before the Court at one and the same time.

Mr. Duncan: Defendant's counsel states that in the absence of his associates he prefers to follow the course

which he and they understand to have been indicated by the Court as the proper course to be pursued in the premises. He does this believing that on the question of the right of defendant to have inspection of the various papers said to be contained in the box in question, a decision of the objection already made by complainant's counsel to the inspection of the one document already designated will practically be decisive of the question as to all the other papers whenever their exhibition by the Examiner shall be demanded.

Counsel for the complainant object to the delivery of the specification, claims and drawing above mentioned, for the purpose stated in the renewed and amended motion for an order to produce of September 9th and 10th, and which purpose is above stated by the counsel for the defendant to be "for the examination of defendant's counsel and for use as evidence herein, if defendant be so advised," upon the ground that such production for the specified purpose cannot be lawfully compelled, nor can the delivery of the papers specified be lawfully compelled for the use of the defendant as above stated.

Complainant's counsel also objects to the production for inspection of the said application, claims and drawing unless the defendant's counsel will state upon the record that they intend to offer in evidence each of the said papers when so produced.

Complainant's counsel also objects to the production, for the purposes aforesaid, of the said specification, claims and drawing, unless the defendant's counsel will state upon the record that it is the intention of the defendant to offer in evidence all of the papers contained in said box, and as above enumerated by Mr. Dyer as part and parcel of the proceedings in the Patent Office connected with such application.

Complainant's counsel gives notice that they will move the Court on Friday, the 28th day of November, 1890, at 11 o'clock, at the opening of Court, for a decision upon the objections above raised, and for a judgment that no sufficient ground has been laid by the defendant to entitle it to the examination and inspection of said documents, and for judgment that the said documents are privileged from such examination and inspection as being copies of documents protected by public policy from such examination in the Patent Office, and for an order directing the redelivery of the same by the Examiner to the complainant's solicitor.

Complainant's counsel requests that the Examiner certify the record to the Court.

The Examiner states that he has marked the papers called for by defendant's counsel, as follows:

"Claims and Specification for Identification, November 25, 1890, and Drawing for Identification, November 25, 1890."

Cross-examination of Mr. Dyer:

By Mr. Duncan: 18 x-Q. In answering the first interrogatory put to you by complainant's counsel, I notice you referred to quite a voluminous memorandum. Will you please produce the said memorandum for the inspection of defendant's counsel?

> Complainant's counsel object, and will state, for the information of counsel for the defendant, that the memorandum handed by him to Mr. Dyer, and afterwards referred to by Mr. Dyer, is merely a copy of the papers contained in the box in question, and, therefore, to deliver that would be to dispose of the question which is now going before the Court.

A. The memorandum I referred to I returned to Mr. Lowrey, to whom you would have to address your request. I cannot produce it myself, and if I had it I would, on advice of counsel, decline to produce it.

19 x-Q. Referring to the papers now in the hands of the Examiner and said to be the papers relating to the Edison application of December 15, 1880, you understand those to be the papers that are referred to in the several motions that have been before the Court, in which the defendant has sought an order for the production of certain papers for the purpose of inspection by defendant's counsel, do you not?

A. I understand that those papers come within the description contained in the motions to which the counsel refers.

20 x-Q. Will you, from your remembrance, state the contents of the specification and the claims of the application made by Mr. Edison, December 15, 1880?

> Objected to, as the primary evidence is now in the custody of the Court, secondary evidence is inadmissible, and the recollection of the witness is not competent until the Court shall have ruled upon the questions hereinbefore raised as to the papers produced.
>
> Defendant's counsel states that he understands the counsel for the complainant to have admitted in the progress of this case that defendant has laid sufficient foundation for the production of secondary evidence in regard to the nature of the said Edison application of December 15, 1880. Furthermore, defendant's counsel states that he does not understand that the document now in the hands of the Examiner, and said to be a "retained copy" of the specification and claims of the said Edison application, is the best or "primary" evidence of the nature of the said application.

A. Without admitting that my recollection is sufficiently accurate to enable me to make such a statement, I must decline to do so on the ground that it would be a violation of my duty to my client, as counsel, to make such disclosure.

21 x-Q. Do you also decline to refresh your recollection, if it be at all at fault, by reference to the retained copy of the specification and claims, and then testify as to the nature of the same?

A. I do.

22 x-Q. Do you make a similar answer in regard to the contents of each and all of the papers in the box now in the possession of the Examiner?

A. I think it would be my duty to do so if a specific question were asked me as to each of these papers?

23 x-Q. Then you admit, do you, that it would be useless for me to ask you as to the contents of those papers?

A. It strikes me so, if the object is to get through me a disclosure of their contents.

Complainant's Exhibit "Defendant's First Notice of Motion to Produce of March 10, 1890." S. M. H. Ex'mr.

UNITED STATES CIRCUIT COURT,

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY, Complainant, against UNITED STATES ELECTRIC LIGHTING COMPANY, Defendant.	In Equity. No. 2445.

Please take notice that on the pleading and proceedings herein and the affidavit of Leonard E. Curtis, a copy of which is herewith served upon you, we shall move this Court, at a Stated Term thereof, to be held for the hearing of motions, in the Court Room, in the United States Post-office Building, in the City of New York, on Friday, the fourteenth day of March instant, at the opening of the Court, at 11 o'clock in the morning of that day, or as soon thereafter as counsel can be heard, that the complainant, its agents, servants or solicitors consent that the Commissioner of Patents furnish to the defendant's solicitors, at their expense, a certified copy of the file wrapper and contents of the pending application of 15th of December, 1880, referred to in the said affidavit of Leonard E. Curtis, and in case of the refusal on the part of the complainant so to do, that all the complainant's proceedings herein be stayed until such consent shall be given, or for such other or further relief in the premises as the defendant may be entitled to or to this Court shall seem just.

Dated New York, March 10th, 1890.

Yours, etc.,
DUNCAN, CURTIS & PAGE,
Defendant's Solicitors,
120 Broadway,
New York City.

To MESSRS. EATON & LEWIS,
Complainant's Solicitors.

UNITED STATES CIRCUIT COURT,

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY
Complainant,

AGAINST

THE UNITED STATES ELECTRIC LIGHTING COMPANY,
Defendant.

In Equity. No. 3445.

SOUTHERN DISTRICT OF NEW YORK, City and County of New York, } ss.:

LEONARD E. CURTIS, being duly sworn, deposes and says, that he is a member of the firm of Duncan, Curtis & Page, solicitors for the defendant herein, and has had general charge of the proceedings on behalf of the defendant in this suit.

That from the testimony of complainant's expert, Professor Barker, taken in complainant's *prima facie* proofs herein, it is made plain complainant at the hearing of this cause will contend that the patent in suit, and notably the second claim thereof, is one of exceedingly broad scope, so broad, in fact, as to include every incandescent lamp in which the burner is composed of a carbon of small cross-section and is sealed up in a globe made entirely of glass, and this irrespective of the particular kind of carbon or the mode of manufacturing the same, or its specific or total resistance, and irrespective also of the form in which said burner is put.

That, as opposed to such construction, defendants take the position that the said second claim, as well as the other claim of the patent in suit, is to be narrowly interpreted, and that when properly construed the patent is so narrow as not to include the lamps made by defendant.

Deponent further says that the construction of the patent above set forth, as contended for by the complainant is, as he believes and as he is advised by defendant's counsel herein, directly opposed to various statements made by the inventor, Mr. Edison, and adopted by his assignee, the corporation complainant, at times shortly before and also shortly subsequent to the date of the said patent. Among the latter, deponent further refers to an application which, he is informed and believes, was filed in the United States Patent Office on or about the 15th of December, 1880; that in the suit of The Consolidated Electric Light Company vs. The McKeesport Light Company, lately heard and decided in the United States Circuit Court for the Western District of Pennsylvania, there was put in evidence the file wrapper and contents of an application for a patent made by Mr. Edison, on or about the 11th day of December, 1879, and the record on that application shows that on the 15th day of December, 1880, Mr. Edison filed an application which he asserted to be a divisional application of the said application. Such divisional application was not made a part of the record in that suit, but it has, for some years past, been a matter of common report among persons who have been connected with the examining corps of the Patent Office, and who have since left the Patent Office and gone into general practice and with some of whom this deponent has had conversations in the premises, that the said divisional application contained very broad general statements in regard to the scope of the alleged invention sought to be patented by it, which were substantially the same in their general character as complainant now contends should be applied to the patent in suit, and also contained various claims intended to cover broadly the use in incandescent lamps of a filament of carbon, said claims being drawn in various forms so as to cover "a filament of carbon of high resistance," "a filament of flexible carbon" and "a filament of high resistance and flexible carbon sealed up in a globe made entirely of glass."

In other words, according to the said information this deponent believes that the said application of Mr. Edison covers the same ground which the testimony of the complainant's expert herein assigns to the patent in suit.

Deponent further says, that it appears from the file-wrapper above referred to as having been offered in evidence in the McKeesport case, that the invention covered by said application had been assigned to the complainant, the Edison Electric Light Company, before the filing of said application on the 15th day of December, 1880, and deponent is informed and believes that said application was then filed with the knowledge and by the procurement of the complainant and at its expense, and has been since prosecuted by the attorneys of the said company and at the said company's expense.

Deponent further says that he is advised by the counsel for the defendant and verily believes that, for the proper interpretation of the patent in suit, it is essential to the defendant's case that the Court should be advised of the exact contents of the said application of December 15, 1880, and the proceedings contained in the file wrapper and contents thereof.

Deponent further says that some two or three weeks

since he brought this matter to the attention of Mr. Richard N. Dyer, one of the counsel of the complainant, and the one who has immediate charge of the management of this suit, and stated to him deponent's belief in regard to the existence and the contents of the aforesaid application, and expressed his desire to have a copy of the same, or the consent of the complainant that he might procure from the Patent Office a copy of the same, for examination and possible use in this case. Mr. Dyer, who has also, as deponent is informed and believes, had general charge of all the patent office work of the complainant for some years past, admitted to this deponent that the application filed by Mr. Edison on the said 15th of December, 1880, was substantially as deponent has above set forth, and that he had a copy of the same and of all the proceedings in the Patent Office regarding thereto, and said further that he would take the matter under advisement and after consultation with his associates would make formal answer to the request for a copy of the said application. Subsequently, to wit, on Monday, March 3d, this deponent received from the said Dyer a written communication, under date of March 1st, in which he says:

"With regard to furnishing you with a copy of
" the papers in the pending application for patent
" of Mr. Edison, filed after the grant of the patent in
" suit, we do not think that you are entitled to them
" nor that we can properly give them. Such papers
" as we have are in our possession as attorneys for
" Mr. Edison and are confidential. The papers in
" the Patent Office, being in a pending application,
" are considered confidential under Rule 15, and,
" having been filed by Mr. Edison under that rule,
" we consider are protected by it. Anyway, it be-
" comes a question between you and the Commis-
" sioner of Patents as to the disclosure of the
" papers in the Patent Office."

Deponent further says that since the receipt of said communication from said Dyer he has caused application to be made to the Commissioner of Patents with reference to the procurement of a copy of the said application, but the said Commissioner has stated that he did not feel at liberty to furnish a copy thereof without the consent of the complainant.

Deponent further says that defendant is ready to pay the cost of a certified copy of the said application.

Defendant's proofs in this case have not yet been closed, and deponent sees no reason why an order of the Court requiring the complainant to furnish a copy of the said application should in any respect delay the progress or the hearing of the same.

(Signed) LEONARD E. CURTIS.

Subscribed and sworn to before me this 10th day of March, 1890.

(Signed) ROBT. F. GAYLORD,
Notary Public (8),
[SEAL.] N. Y. Co.

"Complainant's Exhibit Dyer's Affidavit of March 27, 1890." S. M. H., Ex'r.

UNITED STATES CIRCUIT COURT.

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY,
Complainant,

AGAINST

UNITED STATES ELECTRIC LIGHTING COMPANY,
Defendant.

Equity No. 3445.

STATE OF NEW YORK, City and County of New York, } ss.:

RICHARD N. DYER, being duly sworn, deposes and says as follows: I have read the papers in the matter of defendant's motion to compel the production of the file wrapper and contents of a pending application of Mr. Edison. I am the Richard N. Dyer referred to in the affidavit of Leonard E. Curtis, forming part of said motion papers.

The application for patent in suit was filed November 4, 1879. The patent in suit was granted January 27, 1880. The application for patent, of which the defendant's solicitors move for a copy, was filed, as appears by the motion papers, December 15, 1880. Such papers as I have in my possession relating to the said application are held by me as attorney for Mr. Edison. The papers were received by me in 1882 from the attorney who formerly acted for Mr. Edison in his Patent Office matters. The original papers, I understand, were filed by Mr. Edison, or in his behalf, by the attorney who formerly acted for him in the Patent Office, and that they are now on file in that department.

Rule 15 of the Rules of Practice of the Patent Office is as follows:

"Caveats and pending applications are preserved in secrecy. No information will be given, without authority, respecting the filing by any particular person of a caveat, or of an application for a patent, or for the reissue of a patent, the pendency of any particular case before the Office, or the subject matter of any particular application, unless it shall be necessary to the proper conduct of business before the Office, as provided by Rules 97, 103 and 108."

This rule was in force at the time the application referred to was filed and long prior thereto, and has been in force down to the present time. The said application has never been involved in any interference or other contested proceeding which would entitle other parties to inspect it, and defendant's counsel can have no information with respect to its contents, except such as was obtained in violation of Rule 15. I have never disclosed the contents of this application myself.

The case of the Consolidated Electric Light Co. vs. McKeesport Light Co., referred to in Mr. Curtis' affidavit, was one in which the complainant's interest was substantially the same as the defendant's interest in this case and was represented by the same counsel. A certified copy of an application filed by Mr. Edison December 11, 1879, was put in evidence in the McKeesport case by the complainant therein (*i.e.*, the defendant in this suit); and under a stipulation which has been entered into in this suit either party is entitled to introduce from the record of the McKeesport case any of the depositions or exhibits found therein. While no objection was made to this exhibit in the McKeesport case, nor will there be in this case should the defendant see fit to make use of it, yet it ought to be stated that the certified copy which was used in the McKeesport case was one obtained surreptitiously and in violation of Rule 15 of the Patent Office before referred to,

and without notice to Mr. Edison or his attorney having charge of the application.

Mr. Curtis says in his affidavit that I admitted to him that the application filed by Mr. Edison on the 15th of December, 1880, was substantially as he (Mr. Curtis) sets it out in his affidavit. It might be erroneously inferred from the general character of Mr. Curtis' statement that I had admitted that there would be found in the application referred to statements opposed to or inconsistent with the construction of the patent in suit, and particularly to the second claim thereof, which is being contended for by the complainant in this suit; and also that I had admitted the various matters of detail stated by Mr. Curtis in support of his position as to the legal effect of such application upon the patent in suit.

The fact is as follows: Mr. Curtis asked me to furnish defendant's counsel with a copy of the file wrapper and contents of this application. To this I replied that I would confer with my associates before giving a definite answer. Once or twice after this and before I had been able to see my associates on the matter Mr. Curtis reminded me of it, and I promised to attend to it promptly. After conferring with my associates and before writing the letter of March 3d, quoted by Mr. Curtis, I called upon Mr. Curtis and stated that we had concluded to refuse to comply with his request. Thereupon Mr. Curtis asked me if we would, on motion proceedings, deny that the application existed; to this I replied, "Certainly not." This is the admission Mr. Curtis refers to. I had in mind the fact of the existence of the application and not the nature of its contents.

RICH'D N. DYER.

Sworn to before me this 27th }
day of March, 1890, }

D. H. DRISCOLL,
[SEAL.] Notary Public,
Kings Co.
Certificate filed in N. Y. Co.

Complainant's Exhibit, "Order of Court of April 8, 1890." S. M. H., Exr.

At a stated term of the United States Circuit Court, for the Southern District of New York, held at the Court House in the City of New York, on the 8th day of April, 1890.

Present—Hon. E. Henry Lacombe, Circuit Judge.

The Edison Electric Light Company, Complainant, against The United States Electric Lighting Company, Defendant.	In Equity No. 3445.

The defendant's motion herein that the complainant, its agents or solicitors, consent that the Commissioner of Patents furnish to the defendant's solicitors, a certified copy of the file wrapper and contents of the pending application of Thomas A. Edison, filed in the United States Patent Office on or about the 15th day of December, 1880, or in case of the refusal on the part of the complainant so to do, that all the complainant's proceedings herein be stayed until such consent shall be given, coming on to heard at the Term, after hearing counsel in support of and in opposition to such motion, it is hereby

Ordered, that the said motion be and the same hereby is denied, without prejudice to renewing the same in case all other proceedings to obtain said certified copy prove ineffectual.

E. Henry Lacombe.

"Complainant's Exhibit Renewal of Motion of September 9, 1890." S. M. H., Exr.

CIRCUIT COURT OF THE UNITED STATES,

Southern District of New York.

The Edison Electric Light Company, Complainant, against The United States Electric Lighting Company, Defendant.	In Equity No. 3445.

Please take notice, that on Friday, the 12th instant, at 11 o'clock A. M., or as soon thereafter as counsel can be heard, we shall renew the motion heretofore made (viz., on or about March 14, 1890) for an order that the complainant consent that the Commissioner of Patents furnish to the defendant's solicitors, at their expense, a certified copy of the file wrapper and contents of the pending application for letters patent, filed in the Patent Office of the United States by Thomas A. Edison, on the 15th day of December, 1880, the same being a division of an earlier application, known as the Paper Carbon Application, filed by the said Edison on or about December 11, 1879, together with such other and further relief in the premises as to the Court may seem meet and just.

This motion will be made on the same papers that were used in the former motion of like tenor, together with the decision of the Court made on such former motion, and upon the whole record in the case, and upon the additional affidavit (a copy of which is herewith served upon you) of Leonard

E. Curtis, secretary of the defendant herein, in relation to certain proceedings in the Patent Office and to certain mandamus proceedings more lately had in the premises in the Supreme Court of the District of Columbia.

Duncan, Curtis & Page,
Solicitors for Defendant.

To Eaton & Lewis,
Solicitors for Complainant.

Due service of the above notice and accompanying paper acknowledged this day of

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CIRCUIT COURT OF THE UNITED STATES,

Southern District of New York.

The Edison Electric Light Company,
Complainant,

against.

The United States Electric Lighting Company,
Defendant.

In Equity No. 3445.

State of New York,
City and County of New York. } ss.

Leonard E. Curtis, being duly sworn, deposes and says:

I am the Leonard E. Curtis who, on the 10th day of

March, 1890, made an affidavit in support of a motion similar to that now pending.

Immediately after the denial of said motion (which was decided April 3, 1890) it was decided, upon general consultation among the counsel for the defendant, to apply to the Commissioner of Patents for a certified copy of the file wrapper and contents of the Edison application of December 15, 1880 (referred to in the pending motion); and, thereupon, on the 4th day of April, 1890, such application was made by our counsel S. A. Duncan, and on the following day (viz., April 5), the same was denied by the Commissioner, in the following words:

"You are hereby informed that the decision of "the Commissioner on the above petition is as "follows: 'I do not think that I have the power "'or right to grant this petition, and it is accord- "'ingly denied.'

"By direction of the Commissioner.

"Very respectfully,

"Schuyler Duryee,
"Chief Clerk."

Thereupon, on April 12, 1890, defendant, through its counsel, S. A. Duncan and M. Bailey, filed in the Supreme Court of the District of Columbia a petition, verified by deponent as secretary as aforesaid, praying a writ of mandamus against the Commissioner of Patents directing the said Commissioner to furnish to the relator in said proceeding (the deponent herein), upon the payment of the legal fees therefor, a duly certified copy of the said application of Thomas A. Edison of December 15, 1880, and of the correspondence connected therewith. Upon this petition an order was made by His Honor Judge Montgomery, one of the Justices of said Court, directing the Commissioner of Patents to furnish a copy of the said papers as prayed for, or to show cause, on a day named, why a peremptory writ of mandamus should not issue commanding him to furnish the said papers.

A copy of said order and petition is hereto appended and is marked "Exhibit A."

Subsequently, in obedience to said order, the Commissioner appeared and made answer, a copy of his said answer being hereto appended and marked "Exhibit B."

This answer, as deponent is informed and believes, was prepared by the Commissioner only after full and repeated conferences between his law clerk, Mr. N. L. Frothingham, and the various counsel of the Edison Electric Light Company, and it is deponent's belief that nothing of importance was introduced into said answer or omitted therefrom except with the assent of complainant's counsel.

Upon the filing of said answer the matter was argued before the Court, both orally and in briefs, the Commissioner being represented by Mr. Nathaniel L. Frothingham, who was aided by Mr. Clarence A. Seward, who appeared in behalf of the Edison Electric Light Company, and who also, as counsel for said company, filed a printed brief.

The Court having held the matter under advisement for some time, on the 23d day of June, 1890, announced its decision denying the writ prayed for. An oral statement of reasons for this decision was made by one of the Justices, which statement, on being written out, was handed to the said Justice for revision, but, so far as I can learn, has not yet been filed with the Clerk of the Court.

Appended hereto, and marked "Exhibit C," is a copy of the decision of the Court as entered in the order-book of the Clerk's Office.

LEONARD E. CURTIS.

Sworn to before me this 8th day of September, 1890.

ARTHUR H. SMITH,
Notary Public,
Kings Co.
Cert. filed in N. Y. Co.

"Complainant's Exhibit Amended Notice of Motion of September 10, 1890." S. M. H., Exr.

UNITED STATES CIRCUIT COURT,

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT CO. *vs.* THE UNITED STATES ELECTRIC LIGHTING CO.	In Equity. No. 3445.

Amended Motion.

Please take notice that we hereby amend our motion in the above-entitled case so as to read as follows:

Take notice that on Wednesday, the 24th inst., at 11 o'clock A. M., or as soon thereafter as counsel can be heard, we shall renew the motion heretofore made (viz., on or about March 14, 1890) for an order that the complainant consent that the Commissioner of Patents furnish to the defendant's solicitors, at their expense, a certified copy of the file wrapper and contents of the pending application for letters patent filed in the Patent Office of the United States by Thomas A. Edison on the 15th day of December, 1880, the same being a division of an earlier application known as the paper carbon application, filed by the said Edison on or about December 11, 1879, or, in lieu thereof, at complainant's option, that complainant produce for the examination of defendant's counsel and for use as evidence herein, if defendant be so advised, the full text (either original papers or copies) of said application and of all correspondence in relation thereto which has passed between the Patent Office and the said Edison, or the complainant herein, or his or its attorneys; together with such other and further relief in the premises as to the Court may seem meet and just.

This motion will be made upon the whole record in the case and upon the papers heretofore served upon you.

Duncan, Curtis & Page,
Solicitors for Defendant.

To Messrs. Eaton & Lewis,
Solicitors for Complainant.

Due service of the above notice acknowledged this day of September, 1890.

Complainant's Exhibit "Opinion of Lacombe, J., of October 18, 1890." S. M. H., Exr.

U. S. CIRCUIT COURT,

Southern District of New York.

The Edison Electric Light Co.

against

The U. S. Electric Lighting Co.

For the motion—Messrs. Samuel A. Duncan and Edmund Wetmore.

Opposed—Messrs. C. A. Seward and Grovenor Lowrey.

Lacombe (Circuit Judge):

Complainant is prosecuting a suit for alleged infringement of a patent for incandescent electric lamps (No. 223,898; application Nov. 4, 1879), issued January 27th, 1880, to Thomas A. Edison, and by him assigned to the complainant. On December 11th, 1879, said Edison filed an application in the Patent Office for improvements in electric lamps, and subsequently—namely, on December 15th, 1880—divided such application into two parts, and embodied one division of the same in a new or divisional application of that date. No patent has been issued upon such divisional application. The defendant is endeavoring to prove the contents of such divisional application. In connection with such application the Patent Office has, it is claimed, sent various letters to the applicant, Edison, and to the complainant; and the said applicant and complainant have also sent letters relating thereto to the Patent Office. The originals of the application and of the letters *to* the Patent Office are with the Commissioner of Patents, who also presumably has copies of the letters sent by his office. The complainant has possession of the original letters from the Patent Office, and has copies of the letters to that office and of the application. These papers are in the hands of one of its counsel, who claims that they are privileged communications and refuses to produce them. The proper officer of the complainant corporation has been duly subpœnaed *duces tecum* to produce the papers and declines to do so, refusing to recall them from its counsel so as to obey the subpœna. Application has been made by the defendant to the Supreme Court of the District of Columbia for a *mandamus* to compel the Commissioner of Patents to furnish copies in accordance with the provisions of Section 892 of the U. S. Revised Statutes. That application has been refused. Complainants concede that the application for a *mandamus* and its refusal by the Court puts the defendant in the same situation as if it had duly subpœnaed the Commissioner to appear before an Examiner, and upon his refusal to produce the papers in obedience to such subpœna had applied to the Court in the District of Columbia to punish him for contempt—without success. It was further conceded on the argument that the defendant has done all that is necessary to put it in a position to give secondary evidence of the contents of any of those documents, the originals of which, if present, would be admitted in evidence.

Both of these applications were filed by Edison in pursuance of a contract made with the complainant corporation November 15, 1878. By this he not only transferred to the complainant the inventions which he had already patented, but also expressly covenanted to prosecute with his utmost skill and diligence further necessary investigations and experiments, and to promptly apply for patents for any further inventions and improvements in the field of electric light. He also agreed to prepare or cause to be prepared specifications, &c., of such inventions and improvements "as

may be required by the company," to deliver the same to the company at its request, and to request, upon application for letters patent, that the same be issued to the company as sole owner. By this contract he conveyed to the complainant all such inventions and improvements which he might make for the space of five years after its date. The attorney who prepared, under Mr. Edison's directions the particular application with which this motion is concerned was the complainant's lawyer; and all the expenses of the application were borne by it. The theory on which the defendant seeks to make proof of the divisional application and of the declarations made by Edison and by the complainant in their letters to the Patent Office concerning such application is briefly this:

That there is in the patent sued upon an ambiguity, its language being open to either of two constructions, one a very broad one, the other much more restricted. That, inasmuch, as the language of the patent is the language of the applicant, his admissions are admissible for the purpose of removing the doubt with which his choice of words has surrounded the document. That for the purpose of making application for patents covering inventions and discoveries of the kind conveyed absolutely to the complainant by the contract of 1878, Edison and the complainant are practically the same. That in the particular divisional application, above referred to, Edison uses language which is inconsistent with the claim that in the earlier application (the one for the patent in suit) he used the ambiguous words or phrases in their broad meaning. And, finally, that when the letters to the Patent Office are read in connection with the letters to which they are replies, this fact will still more plainly appear.

This argument deals, of course, with the *materiality* of the proposed evidence when produced, and to this motion, which is practically directed to securing its presence in Court, the complainant objects that the evidence, if produced, would be immaterial. That question, however, should not be determined upon application to produce the papers. The Court should pass upon it with the proposed evidence before it so that it may act intelligently and that an exception to its refusal to admit the testimony (should it so refuse) may be of avail to the exceptant upon appeal. If the *only* objection to admitting these documents in evidence be that they are *immaterial*, that objection is of no avail in opposition to an application which calls for their production. Without, therefore, finally determining the question as to the materiality of these documents, it is sufficient to say that in view of the contract relations between Edison and the company and of the rule of law as to the admissibility of a party's admissions, and in view of the effect accorded to such admissions in the case cited by defendant (Giant Powder Co. vs. California Co., 4 Fed. Reporter, 720), and, finally, in view of the contents of the documents as disclosed by the moving papers, there is not found in the objection as to the materiality of the evidence sufficient to warrant the refusal of the officers of the corporation to obey the *subpœna duces tecum*, and to produce the documents, which are concededly in the hands of its counsel, subject to its orders and under its control.

It is, however, further objected that the documents are privileged. That the application and the letters patent are the result of consultations between the applicant and his counsel. That their phraseology must necessarily reflect both the information given by the client to the counsel and the advice given by the counsel to the client; and that they have been placed in the hands of counsel under the protection of the confidential relation.

Of the various cases cited upon the argument many deal with the question as to the duty of the counsel.

Corning vs. Tandsahill, 1 Hill, 33.
Wright vs. Mayer, 6 Vesey, 280.
Dale vs. Denison, 4 Wend., 558.
Kellogg vs. Kellogg, 6 Barb., 116.
Chirac vs. Reinicker, 11 Wheat., 280.
Conn. Mut. Life Ins. Co. vs. Schafer, 94 U. S., 457.
Hibbard vs. Knight, 2 Exchequer, 11.
Rex vs. Dixon, 3 Burr., 1687.

In the case last cited, Lord MANSFIELD said that instead of producing the papers the attorney ought immediately, upon receiving the subpœna, to have delivered them up to his client.

The defendant, however, is not contending upon this motion that Mr. Dyer, the counsel who received these documents, is under any obligation to produce them in response to the subpœna, or to testify as to their contents. The only question now presented is whether the complainant's officers, under whose control the documents now are, who have the power to call them back from the possession of counsel (even if he has not in accordance with the suggestion of Lord Mansfield, above quoted, already returned them), can excuse themselves from producing these documents in response to the subpœna, upon the theory that they are privileged as being the subject or the result of confidential communications between client and counsel. If documents are not privileged while in the hands of a party, he does not make them privileged by merely handing them to his counsel. The latter may, perhaps, properly refuse to produce them, but the former cannot do so merely because he is prepared to say that he has shown or has delivered them to his counsel. The converse of this proposition was contended for by the complainant upon the argument, but the authorities cited do not sustain such contention. In Southwick Water Co. vs. Quick, 3 Q. B. Div., 315, transcripts of shorthand notes of interviews between officers and employees of the company, which interviews were had with the object of obtaining statements of fact to be furnished to counsel for the company, for the purpose of securing his legal advice touching an intended action were held privileged. In Wheeler vs. Le Marchant, L. R. 17 Ch. Div., 683, the question was as to whether certain written communications which had passed between the solicitor of the defendants and their surveyor and between the surveyor and the solicitor were privileged. The Court held that they were *not*, except such as were prepared after dispute had arisen between plaintiffs and defendants and for the purpose of obtaining information, evidence or legal advice, with reference to litigation existing or contemplated between the parties. Certainly, neither of these cases supports the proposition that a party may secure for a document, not otherwise privileged, the protection of the rule by handing it to his counsel. It is urged, however, that these papers are privileged, because they are the result or product of confidential consultations between client and counsel. This argument applies, of course, only to the application and to the letters *to* the Patent Office. The principles deducible from the authorities cited and from others which have been examined seem to be these: Neither client nor counsel may be asked as to mutual communications induced by their confidential relation, nor can either be required to produce any document emanating from one and transmitted to the other in the course of such confidential relation. The client cannot be required to produce letters written by him to his counsel stating the facts as to which he wished advice nor letters from his counsel embodying that advice or even asking for further facts. If, as the result of the consultation between client and counsel there is prepared some document, such as a form of contract or a notice or a letter, and that document is given by one to the other, and by him *kept*, it is probably privileged, its contents being confidential between client and counsel, and the document itself effectual only as an expression of the statement of the client as to the facts and of the opinion of the counsel as to what kind of document it is desirable to prepare in view of the facts (Genet vs. Ketchum, 62 N. Y., 626). But if the document thus confidentially prepared is not so kept; if the contract is by the client executed with some third person, or the notice is given, or the letter sent to some outsider, its contents are no longer confined to the knowledge of client and counsel, and the party can no longer, as to a document which he has thus made public, claim that it is privileged because it is confidential. Such seems to be the rule fairly deducible from the decisions.

Minet vs. Morgan, L. R., 8 Ch., 361.
Pearse vs. Pearse, 11 Jurist., 52.

Conn. Mut. Life Ins. Co. vs. Schafer, 94 U. S., 457.
Corning vs. Tandsahill, 1 Hill, 33.
Whiting vs. Barney, 30 N. Y., 330.
Randolph vs. Quignic Co., 23 Fed. Rep., 278.
Foakes vs. Webb, 28 L. R. Ch. Div., 187.
Ford vs. Tenant, 9th Jurist, N. S., 292.
In re. Whitlock, 15 Clv. Proc., 204.
In re. Whitlock, 51 Hun, 351.
In re. Mitchell, 12 Abb. Prac., 249.

The complainant, however, contends that the documents are privileged, because they are communications passing between the applicant and the Patent Office touching an unissued patent. The existence of no such general privilege is recognized in any of the authorities cited. (See also the exhaustive enumeration of authorities given in *Whiting vs. Barney* and *In re Miller, supra;* and also the cases cited in *Greenleaf on Evidence*, §§ 250, 251 and 252, and in *Wharton on Evidence*, §§ 604, 604*a*, 604*b*.) Nor has any express legislation created it. By Section 4902, U. S. Rev. Stat., Congress has provided that *caveats* and descriptions, specifications, &c., interfering with such *caveats*, shall be filed in the confidential archives of the Patent Office and preserved in secrecy; but there has been no such legislation as to pending applications.

The complainant relies upon a rule or regulation of the Patent Office, as follows:

"15. Caveats and pending applications are preserved in secrecy. No information will be given, "*without authority*, respecting the filing by any particular person of a caveat or of an application for a "patent or for the reissue of a patent, the pendency of "any particular case before the Office, or the subject "matter of any particular application, unless it shall "be necessary to the proper conduct of business before "the Office, as provided by Rules 97, 103 and 108."

That rule has been established under authority of Section 483 U. S. Rev. Stat., which provides that "The "Commissioner of Patents, subject to the approval of "the Secretary of the Interior, may from time to time "establish regulations *not inconsistent with law for the* "*conduct of proceedings in the Patent Office.*"

This rule, so far as it regulates the conduct of proceedings in the Patent Office, is binding upon all the subordinates in that office, possibly also upon the Commissioner of Patents himself unless he obtains the assent of the Secretary of the Interior to its total or partial abrogation; but it is inoperative to change the rules of evidence in courts of justice, both because to that extent it would be inconsistent with law, and also because the effecting of such a change is in no sense the regulation of proceedings in the Patent Office. Under a somewhat similar section (Section 252), the Secretary of the Treasury, under direction of the President, is authorized to establish regulations, not inconsistent with law, to secure a just appraisal of imported goods. If under such authority he should make a rule that no examiner or assistant appraiser should give information to any one as to the methods by which he ascertained the composition or quality of such imported goods as he examined, such rule might be binding upon the subordinate as to any voluntary disclosures, but would certainly not excuse him from testifying in Court if the sufficiency of his examination of the goods were made the subject of judicial inquiry.

The refusal of the company's officers to produce the documents in question under subpœna *duces tecum* cannot therefore be excused upon the theory that they are privileged communications.

The specific relief prayed for on this application is for an order "that the complainant consent that the Commissioner of Patents furnish to the defendant's solicitors, at their expense, a certified copy of the file wrapper and contents of the pending application for Letters Patent filed in the Patent Office of the United States by Thomas A. Edison, on the 15th day of December, 1880, the same being a division of an earlier application known as the paper carbon application, filed by the said Edison on or about December 11, 1879, or, in lieu thereof, at complainant's option, that complainant produce for the examination of defendant's counsel and for use as evidence herein, if defendant be so advised, the full text (either original papers or copies) of said application and of all correspondence in relation thereto which has passed between the Patent Office and the said Edison, or the complainant herein, or his or its attorneys." Sufficient ground for the making of such an order, if it be within the power of the Court to make it, is not shown. It does not appear that the commands of the subpœna *duces tecum* will not be ample to obtain such evidence as that described in the motion.

Merchants' Nat'l Bank vs. State Bank, 3 Cliff., 202.

Bischoffheim vs. Brown, 29 Fed. Rep., 743.

Certainly as to the letters from the Patent Office, the originals of which are in the possession of the complainant, the writ of subpœna should produce the best evidence; and as to the copies of the application and of the letters *to* the Patent Office, sufficient foundation having been laid for the admission of secondary evidence, they may be offered when produced and identified with the same effect as if they were originals.

The notice of motion, however, also contains a prayer for general relief, and under that prayer the defendant may take an order committing the officers of the corporation for contempt in failing to obey the subpœna *duces tecum*.

October 18, 1890.

(Signed) E. Henry Lacombe.

Complainant's Exhibit "Order of Court of November 5, 1890." S. M. H., Ex'mr.

At a Stated Term of the United States Circuit Court for the Southern District of New York, held in the City of New York on the 5th day of November, 1890.

Present—E. Henry Lacombe, Circuit Judge.

The Edison Electric Light Company, Complainant, against The U. S. Electric Lighting Company, Defendant.	In Equity. No. 3445.

This cause coming on to be heard on the 8th day of October, 1890, upon motion made in behalf of the defendant for "an order that the complainant consent "that the Commissioner of Patents furnish to the de- "fendant's solicitors, at their expense, a certified copy "of the file wrapper and contents of the pending appli- "cation for letters patent filed in the Patent Office "of the United States by Thomas A. Edison, on "the 15th day of December, 1880, the same being "a division of an earlier application, known as the "'paper carbon application,' filed by the said Ed- "ison on or about December 11, 1879, or in lieu "thereof, at complainant's option, that complain- "ant produce for the examination of defendant's "counsel, and for use as evidence herein, if defendant "be so advised, the full text (either original papers or "copies) of said application and of all correspond- "ence in relation thereto which has passed between "the Patent Office and the said Edison, or the com-

"plainant herein, or his or its attorneys, together with "such other and further relief in the premises as to "the Court may seem meet and just;" and argument having been had upon the said motion, both orally and by briefs, C. A. Seward and G. P. Lowrey, Esqs., appearing for the complainant, and S. A. Duncan and E. Wetmore, Esqs., for the defendant; and it appearing by the moving papers that the corporation complainant is in possession of the originals or copies of the aforesaid divisional application of December 15, 1880, and of the correspondence which has passed between the Patent Office and the said Edison, or the said Edison Company, or his or its attorneys, in relation to the same, and the subpœnas *duces tecum* have been duly served upon Jacob H. Herrick, president of the corporation complainant, and upon F. S. Hastings, the secretary of the said company, commanding them to produce the said papers before S. M. Hitchcock, Esq., one of the Examiners of this Court; and that the said Herrick and the said Hastings have refused to obey the said subpœnas and to produce the said papers, and by reason thereof are guilty of contempt; and the Court having considered the premises.

Now, therefore, it is hereby

Ordered, that the said Herrick and the said Hastings produce the said papers as required by the aforesaid subpœnas within ten days hereof, or show cause before me why they should not be punished for contempt in disobeying the commands of this Court.

(Signed) E. Henry Lacombe.

"Complainant's Exhibit Judge Lacombe's Opinion of November 24, 1890." S. M. H., Ex'r.

CIRCUIT COURT OF THE UNITED STATES,

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY, Complainant, AGAINST THE UNITED STATES ELECTRIC LIGHTING COMPANY, Defendant.	No. 3445.

The documents called for by the subpœnas have now been brought into Court. In excuse for not delivering them to the Examiner it was urged that some further objection to their presentation in evidence is to be made, which counsel thought should be made not before the Examiner, who sits without power to rule upon objections, but before the Court. The motion to punish for contempt is therefore denied. The papers are delivered to the Examiner. When any one of them is called for by counsel for the defendant, if objection to its exhibition is made by counsel for plaintiff, the Examiner will certify the objection to the Court and send therewith the document itself. Thereupon the Court will rule upon the objection. As this will practically be a continuance of the matter argued last Friday, the case may be put as unfinished business at the head of the calendar on next motion day.

E. HENRY LACOMBE.

NEW YORK, December 20, 1890.

Met pursuant to notice.

Present—R. N. DYER, ESQ., of counsel for complainant; SAMUEL A. DUNCAN, ESQ., of counsel for defendant.

Complainant's counsel offers in evidence a certified copy of the file wrapper and contents of Letters Patent No. 282,030, granted July 31, 1883, to Isaac Adams, Jr., for Incandescent Electric Lamp, and the same is marked "Complainant's Exhibit File Wrapper and Contents of Adams Lamp Patent."

Objected to as immaterial, also for the reason that if the record of the Adams patent be offered for the purpose of proving admissions by the said Isaac Adams, Jr., the attention of the said Adams, who has been examined as a witness in the cause, should have been called to this record while he was upon the stand. Complainant's counsel having failed to do this, it is believed that the record is not admissible.

Complainant's counsel gives notice that the complainant has closed its rebutting proofs as the record now stands.

<u>Edison Electric Light Co.</u> v. <u>United States Electric Lighting Co.</u>

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Complainant's Rebuttal - Exhibits

CIRCUIT COURT OF THE UNITED STATES,

SOUTHERN DISTRICT OF NEW YORK.

IN EQUITY, 3445.

THE EDISON ELECTRIC LIGHT COMPANY,

Complainant,

vs.

THE UNITED STATES ELECTRIC LIGHTING COMPANY,

Defendant.

ON LETTERS PATENT No. 223,898.

VOL. VI.

COMPLAINANT'S REBUTTAL

EXHIBITS.

DEFENDANT'S EXHIBITS.

EATON & LEWIS,

Complainant's Solicitors.

CLARENCE A. SEWARD,
GROSVENOR P. LOWREY,
RICHARD N. DYER,

Of Counsel.

C. G. Burgoyne, 146-150 Centre Street, N. Y.

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British Patents:

Defendant's Exhibits—Printed—*Continued.*

Defendant's Exhibits—Printed—*Continued.*

Complainant's Exhibit "Preface first Edition of Fontaine; Higgs' Translation." March 13, 1890. S. M. H., Exr.

ELECTRIC LIGHTING.

A PRACTICAL TREATISE

BY

HYPPOLYTE FONTAINE.

Translated from the French.

By PAGET HIGGS, LL. D., Assoc. Inst. C. E.

London, 1878.

PREFACE.

Our purpose in publishing this work is to show what are, in the present state of science, the judicious applications of electric lighting; as much as to record the services that this new light is capable of rendering a multitude of industries, as to combat false ideas founded on the possibility of its universal use.

Few questions have at the present time the advantage of exciting public attention to the extent of this one; trials have been made in France, England, Germany, Russia, Belgium, Sweden, Austria, Spain, America; on vessels, quays and dock-yards; in workshops, harbors, fortifications, railway stations, &c., &c. It is of general interest.

In this century, when progress is so rapid, many persons do not await the sanction of experience before exalting a new invention to the detriment of all others; these persons have scarcely had time to admire the marvelous effects of gas-lighting than they salute the dawn of electric lighting by proclaiming that it is a hundred times more economical than the former, that we can employ it everywhere, distribute it indefinitely, and that its light is as beautiful and intense as that of the sun itself.

Other persons, unfortunately more numerous than the former, wish no departure from routine, and hinder by their inertia the march of all progress. For them, the electric light has no industrial existence; it is a will-o'-the-wisp, dazzling those who regard it, and so fatiguing the eye that its use is materially impossible.

We ignore surprises that the future may reserve for us; but our knowledge of the subject leads us to affirm that the *rôle* of electricity is far from its full development, especially from the point of view of the transformation of motion into light. It is

not of so much importance to know what will be, as to know what is. And it is to this end that we present a study of the elements of electric lighting that have definitely entered the domain of practice, and of the best conditions for its use. Later, as perfections are more nearly attained, we shall put them so much better to profit that we can better appreciate the advantages; it appears to us irrational to neglect the use of what is already good, under the pretext that we shall one day arrive at something more nearly perfect.

The electric light may be utilized in two ways, either by powerful foci illuminating or visible at great distances or by less intense foci giving a light suitable to all kinds of night work. In the first case, nothing can equal the services rendered by electricity; in the second case there is no longer comparison, the advantage being sometimes in favor of gas, oil, petroleum, &c., sometimes in favor of electricity.

Thus for lighthouse service, fortifications, maritime service, shores, armies and campaign, the electric light is superior to all others; for show-rooms and manufactories, for open air yards and large work shops it is equally suitable; for domestic household illumination, and for certain trades carried on under low roofs, where there are numerous local subdivisions, gas, oil or petroleum is preferable. In many establishments lighted by gas it has been advantageous to substitute electricity.

In any case, the number of applications would be very limited if we should continue to deprive ourselves of light, as it is the custom to do in the majority of manufactures, where during the night superintendence is impossible where the work produced during the night is much less than in the day. But, we hasten to add, this *statu quo* is not to be feared; some intelligent manufacturers—and their number is great—will replace their present system of lighting by a system of lighting four or five times more intense, and they will not hesitate to admit that their products are better, in larger quantities, and consequently more economical; this example will not be lost, and to sustain competition their fellow-manufacturers will imitate them.

In support of this opinion it is sufficient to recollect that the Gramme machine, with which the electric light is practically obtained, had not last year * more than a dozen applications, whereas to-day it numbers more than two hundred. However, this new machine has not failed to receive criticism. It has been said to become heated, difficult to work, clumsy, capricious, that it could not be worked ten hours without repairs. The truth is, it works perfectly, and, instead of deteriorating, improves by use.

Our work is divided into twelve chapters. The first six are devoted to the study of the voltaic arc, the carbons, the lamps or regulators, and some magneto-electric machines; the last six treat of realized applications, the comparative costs of several sources of illumination, of lighting by incandescence, and of the division of the electric light.

Those persons simply seeking for information as to the possibility of utilizing the electric light for themselves, should read Chapters VII., VIII., and IX., which contain all the necessary information for planning and appreciating the advantages to be gained by this system of illumination.

We have dwelt somewhat on experiments made by scientfic men to determine the nature and properties of the voltaic arc; this was the origin of the new method, and it is important to explain thoroughly the phenomena which have given birth to the remarkable applications that we subsequently cite, in order to admit of the better exercise of judgment.

The study of regulators or lamps could have been made the subject of a special work as regards the proposed and attempted types; but most of these apparatus have numerous drawbacks, and we have preferred to mention only those presenting originality, such as might serve as basis for a new invention, or warn seekers against combinations judged impracticable. M. Serrin's apparatus should have, and in effect has, the honors of our record, as being to the present time the only one susceptible of advantageous use in industry.

The manufacture of carbon rods, intended to supply the regulators and to become heated under the influence of the electric fluid, has an exceptional importance; upon this, perhaps, depends the success of electric lighting. To this we have

* M. Fontaine writes in 1877.—Trans.

devoted a long chapter, and have minutely detailed the processes of Messrs. Carré and Gaudoin, which are the most perfect. Some exact experiments on the quantity of light produced by several carbons complete these descriptions.

Before attempting the study of the Gramme machine, we have passed in review the principal magneto-electric machines that have preceded it, and, with the aid of numerous engravings, we hope to have made clear, even to those little initiated in modern physics, the principle of these marvellous machines that create such torrents of electricity without acid or consumption of metal—with nothing more than the influence of magnets and coils of copper in relative motion.

The Gramme machine being applied only in constructive workshops, it is useful to speak of it at length; to well distinguish its principle, its mode of construction, and its multiple effects. Here again it has been necessary to make use of drawings in order to explain the apparatus and show the several forms it has assumed.

But it is especially in the part devoted to the applications that we have entered into precise detail, by insisting particularly on the motive force expended, and on the true cost price of the electric light. To evaluate the motive force, we have at our disposal the reports of Messrs. Tresca, Member of the Institute (of France); Hagenbach, Professor at the University of Bâle; and Schneider, Professor of Physics at Mulhouse. For the comparison of the cost prices of several lights, we have drawn upon some sources of authority, chiefly from persons who have for several years employed this new system of lighting. The applications to marine, artillery, or civil purposes have not been signalized by great development; for the several Governments who have experimented with the Gramme machine have kept secret all the results observed. Nevertheless, numerous and important orders, obtained after prolonged trials, authorise us in saying that success has been complete.

Mechanical workshops have been the first to make use of the electric light; also dyers, who need a very white light; and sugar refineries, where steam is produced very economically. Railway companies have adopted it for the illumination of their goods depôts; contractors for public works, for the execution during the night of earthworks or mason-work; finally it has been introduced with success into spinning mills, smithies, foundries, &c.

Three years ago much was said about a new system of electric lighting, the invention of a Russian professor, which consisted in causing the incandescence of a small rod of carbon. It was for some time believed that by the aid of this invention the light could be in some way indefinitely divided, and introduced everywhere for nearly nothing. Deeper study of this subject, and numerous direct experiments have enabled us to reduce this system to its real value, which, if it be defective when we consider it as capable of causing a revolution in present lighting, is very remarkable, on the other hand, when we have in view only a small number of special applications.

The Jablochkoff candles, about which also much was said, appear to us to merit the same appreciation. If they result in anything practical, which is very possible, they will be useful in certain cases, but will be substitute for nothing absolutely. In spite of our sympathy for the inventor, we have to guard the reader against the exaggerations founded on some experiments made in a Paris warehouse, and bring to their true value the consequences that may be logically deduced from these experiments.

Finally, we conclude our analytic review with the description of means attempted for the division of the light, and with some consideration of the present state of the question.

We have consulted the following special works, and borrowed from them several interesting notes:—The physical treatises of Messrs. Jamin, Daguin, Ganot, Pouillet; the electrical treatises of Messrs. Becquerel, de la Rive, du Moncel, Jenkin, Guthrie; the treatises on light of Messrs. Tyndall, Becquerel, Moitessier; M. Cazin's 'L'Étincelle Electrique,' M. Niaudet-Breguet's 'Machines Gramme,' M. Figuier's 'Merveilles de la Science,' Abbé Moigno's 'Les Mondes,' M. Leroux 'Machines Magnéto-Electriques Françaises,' the collection of the 'Comptes Rendus de l'Académie des Sciences,' 'Les Bulletins de la Société d'Encouragement,' and the collections of French and English patents.

Our searches in the collection of French patents have procured some very curious information; we have abstracted thence more than one hundred descriptions of apparatus, of which we have published only a very small part, giving, preferably, favor to practical applications, as the principal object of our labor.

Among these old inventions are a goodly number now represented under other names, and that we have believed to be new. It would be easy to cite more than one patent that is a rejuvenation of old combinations, and of which it may be said, in the words of a certain inventor, "The people of former times had little honesty; they have stolen all my ideas."

Complainant's Exhibit "Chapters XI. and XII., 1st Edition of Fontaine; Higgs' Translation," Feby. 28, 1890. S. M. H., Exr.

CHAPTER XI.

LIGHTING BY INCANDESCENCE.

Use of Geissler Tubes—Report presented to the Academy of Sciences by M. Coste, in the name of M. Gervais—King's Invention—Lodyguine's Lamp—Wild's Report to the St. Petersburg Academy—Konn's Lamp—Boulíguine's Lamp—Experiments by the Author on Lighting by Incandescence—Chérémeteff and Fontaine's Lamp.

As we have said, the voltaic arc is eminently convenient for the lighting of large uncovered spaces, or large halls without interior partitions, but when it is required to light small places or very subdivided localities, it is much more advantageous to employ gas, petroleum, or even ordinary oil.

There are numerous works on the construction of small electric foci, but to the present day none of the means devised have given practical results. It has been endeavoured to use Geissler tubes, and small incandescent carbons, and if these two means have not been successful, they offer nevertheless sufficient interest that we should devote some pages to their description.

It is well known that Geissler, an artist at Bonn, constructed the first tubes blown in various forms, closed hermetically and containing only traces of various vapours. These tubes put into communication with a current, by means of platinum wires fused into the glass, from a Ruhmkorff coil, produce a stratified light, that is to say, composed of fine transverse layers separated by dark layers continually agitated. At the same time the sides of the tubes present a brilliant appearance, to which the term fluorescence has been applied.

On March 27, 1865, M. Coste presented to the Academy of Sciences, in the name of M. Gervais, the following report:

"The apparatus was constructed by M. Ruhmkorff, who has acquitted himself of his task with his usual care and ability. It is a case or box in bronze, mounted on four feet, and its cover

or lid is hermetically closed by means of a press-screw, and between the two surfaces thus brought into contact is a caoutchouc washer. To the cover is attached a ring, serving as a suspension to the optical apparatus. The case contains two bichromate of potash elements closed in their turn by plates to which strips of copper are solidly screwed. The poles of the current furnished by these two elements may be put at will into communication with the bobbin, and the induced current is transmitted to a Geissler tube by two wires covered with india-rubber. This tube, of proper form and filled with carbonic acid, is enclosed in a glass cylinder with thick sides, furnished with copper armatures, and into which water cannot penetrate. This is the lighting part of the apparatus. With this instrument a soft light is obtained, similar to that now employed by miners. It resembles in certain respects that given by phosphorescent animals, but is more intense. It can be seen even when the apparatus is several mètres under water. It would doubtless serve to attract fish, as does the phosphorescence of certain species, and it would also serve to light limited spaces, situated beneath the surface of the water, or for floating signals. The captain of the 'Devoulx,' commanding the southern coasts of France, employed this apparatus in the port of Cette, in September last. It remained immersed for nine hours, and it gave light for six hours, under these conditions, as well as when charged at Montpellier. The phosphorescence may be of longer duration. A second trial, made at Port Vendres, on board the 'Favori' (Captain Trotabas), was equally successful."

The light obtained by the Geissler tube is so feeble, that it can never be utilised practically, and numerous trials made in mines and powder mills have been without result.

Lighting by incandescence has been studied for a long time; but its application generally presents so great difficulties, that at the present day it may be considered as within a purely scientific domain; although a certain number of apparatus exist working moderately well.

The first document on the question that we have found, is an English patent of the 4th November, 1845.

Mr. King, the inventor, enters into some exact details of his idea, and presents some considerations which tend to prove that magneto-electric machines, powerful enough to produce light, already existed in 1845.

The following are the principal passages from this patent:

The invention has for its basis the use of metallic conductors, or of continuous carbons, heated to whiteness by the passage of an electric current. The best metal for this purpose is platinum, the best carbon is retort carbon.

When carbon is employed, it is useful on account of its affinity for oxygen at high temperatures to cover it from air and moisture, as indicated in Fig. 45. The conductor C rests on a bath of mercury; the bar B is in porcelain, it serves to support the conductor C; the conductor D is fixed on the bell by a hermetically sealed joint. The carbon rod A rests at top and bottom on conducting blocks and becomes incandescent by the passage of an electric current.

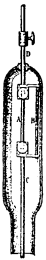

FIG. 45.
KING'S LAMP.

A vacuum is previously established in the bell, and the apparatus veritably forms a barometer with one of the poles of the battery in communication with the column of mercury, and the other with the conductor D.

In order to obtain an intermittent light, the circuit can be periodically interrupted by a clock-work movement.

The apparatus properly closed may be applied to submarine lighting, as well as to the illumination of powder mills and of mines, especially where the danger of explosion is feared, or the rapid inflammation of very combustible substances.

When the current is of sufficient intensity, two or a larger number of lights may be placed in the same circuit, care being taken to regulate the power of the magneto-electric machines, or the elements of the battery producing the current.

In 1846, Greener and Staite filed a patent for a lamp, analogous to King's, pointing out that they freed the carbon,

before use, from impurities by treatment with nitro-muriatic acid.

In 1849, Petrie concludes the description of a patent for a lamp with the following remark:—"A light may be produced by passing an electric current through a short and thin conductor, which heats and becomes luminous; but the majority of substances fuse and burn rapidly: however, I obtain a good light by using iridium, or one of its alloys. Iridium may be fused so as to produce an ingot whilst it is submitted to the heat of the voltaic arc; afterwards it may be decarbonised and rendered more malleable. It can be cut into small pieces of 0·001 mètre diameter and 0·010 to 0·020 mètre length, that can be fixed upon two insulated metallic supports, which are in connection with the two wires of a proper galvanic battery. There is then obtained a beautiful light."

Several other patents have been taken out in America, France, and England for the same kind of idea; but none of these appear more complete, more explicit, and more practicable than King's; it is then useless to continue our nomenclature.

Lighting by incandescence, and the principle of its production, had for a long time fallen into oblivion, when in 1873 a Russian physicist, M. Lodyguine, resuscitated both, and invented a new lamp, which has since been perfected by Messrs. Konn and Bouliguine.

In 1874, the St. Petersburg Academy of Sciences awarded a high prize to M. Lodyguine. The following includes some extracts from the report presented on the occasion by M. Wild, director of the Imperial Observatory; this report, as we shall see, includes several capital errors:

"It has long been known that we can employ the heating faculty of the electric current, even without the aid of gas, as in the luminous galvanic arc, to heat a solid body to whiteness. On this principle there are often thus heated thin platinum wires, which are bad conductors, by causing them to be traversed by a powerful electric current. The light obtained by this process is much more feeble and more constant than the electric light from carbon; it can also be extended further, and may be increased or diminished at will; nevertheless it has never found practical use, because it is too feeble compared with its cost, and because when it is desired to give greater intensity, there results fusion of the platinum wire, which in general is not homogeneous throughout.

"M. Lodyguine was the first who had the idea of replacing the platinum wire, in these combustion experiments, by small bars of carbon (coke) analogous to graphite, that is to say, a good conductor, and thus resolved the problem of electric lighting.

"The advantages of this substitution of the carbon for platinum are so obvious from a theoretical point of view, that it is astonishing, as is always the case with important inventions, that no one had the idea sooner. Carbon possesses at equal temperature much greater power of radiation than platinum; the capacity for heat of platinum is superior (nearly double) that of the carbon in question, so that the same quantity of caloric raises the temperature of a small bar of carbon to a degree nearly twice that attained by a platinum wire of the same volume. Besides the resistance of the carbon in question, as a conductor of electricity, is nearly 250 times greater than that of platinum; it results that the small rod of carbon may be fifteen times thicker than a platinum bar of the same length, and that the current traversing it will engender the same quantity of heat. Finally the carbon may by heated to the most extreme white heat without fear of fusion, as is the case with platinum. It is to these important theoretical advantages that is evidently due the great success of the mode of electric lighting proposed by M. Lodyguine.

"The sole inconvenience of the use of carbon instead of platinum consists in the fact that, in the combustion the carbon combines with the oxygen of the air, and is thus gradually consumed. M. Lodyguine has avoided this inconvenience by enclosing the carbon heated to whiteness by the electric current in a glass receiver hermetically sealed, and from the interior of which the oxygen is expelled by a most simple process.

"It is not within the province of the Academy of Sciences to give its judgment on the technical and other difficulties which will present themselves in the extended application of M. Lodyguine's invention, nor on the other hand, upon the numerous practical advantages of this mode of lighting above all others; it will suffice to the Academy to state that, thanks to this invention, there is resolved in the simplest possible manner the great problem of subdivision of the electric light, and of rendering it constant,* in order to recognise M. Lodyguine as worthy, in consideration of the numerous applications of his invention, to obtain the Lomonossow prize."

In his lamp, M. Lodyguine employs carbon in a single piece by diminishing the section at the point of the luminous focus, and he places two carbons in the same apparatus with a small exterior commutator, in order to pass the current into the second carbon, when the first has been consumed. Nothing is less practical nor less studied than the apparatus of this inventor.

M. Kosloff, of St. Petersburg, who went to France in the hope of working the Lodyguine patent, perfected his lamp slightly, without, however, bordering upon anything passable.

In 1875, M. Konn, also from St. Petersburg, patented a more practicable lamp, represented in Fig. 46, which was constructed for the first time in Paris by M. Duboscq.

This lamp consists of a base A in copper, on which are fixed two terminals N for fastening the conductors, two bars C, D in copper, and a small valve E opening only from within outwards. A globe B, widened at its upper part, is retained on the base by means of a bronze collar L pressing on an india-rubber ring, exactly as occurs with the level-gauges of steam-boilers.

One of the vertical rods D is insulated electrically from the base, and communicates with a terminal also insulated. The other rod C is constructed in two parts: (1) of a tube fixed directly upon the base without insulation, and (2) of a copper rod split for a part of its length. This split gives elasticity, and admits of the rod sliding in the tube with only a small effort.

The retort carbons E, to the number of five, are placed between two small plates which crown the rods.

Each carbon is introduced into two small blocks, also of carbon, which receive the copper rods at their extremities. The rods also are equal in length at their lower ends, and of unequal length at their upper ends. A hammer I is hinged on the bar C,

* We shall see subsequently how the problem has been resolved by M. Lodyguine.

and rests only on a single rod of carbon at once. If this lamp is placed in circuit by attaching the two conductors from a battery to the terminals N, N' (the terminal or binding screw N' is hidden by the terminal N; but it is identical, and is not insulated from the base), the bar of carbon E is traversed by the current which passes by the aid of the hammer I, from the copper bar F, the two carbon blocks O, O, the copper bar G, and the plate crowning the bar D.

The vacuum has previously been made by putting the cock K in connection with an air-pump or other known pneumatic machine.

The rod E reddens, whitens, and becomes luminous. Its light is colourless, steady, and constant; but gradually the section diminishes, the rod breaks, and the light disappears. The hammer I then falls on another rod, and nearly instantaneously lighting is re-established.

When all the carbons are consumed the hammer rests upon the copper rod H, and the current is not interrupted. In this manner when several lamps are fed by the same electric generator, extinction of one does not cause that of the others.

To avoid the projection of small pieces of carbon and their blocks against the glass, M. Konn has placed at the lower part of his lamp a small copper tube M, which receives the *débris* until the plates are refurnished.

Three of these lamps were introduced two years ago at the house of M. Florent, a merchant of St. Petersburg, and put in action with an "Alliance" machine. Each carbon lasts about two hours, with the exception of the first, which is consumed nearly immediately; the light is very agreeable, but its cost considerably exceeds that of gas. M. Florent, whom we have had occasion several times to see, has informed us that the great advantage he has found in the employment of electric lighting was its cleanliness. His store-rooms contain much white linen that gas rapidly impairs, and on which electricity exercises no injurious influence. The bleaching economised fully compensates the supplementary cost necessitated by an important introduction, with but little regard to the light obtained.

M. Florent has not made any photometric measurement; but,

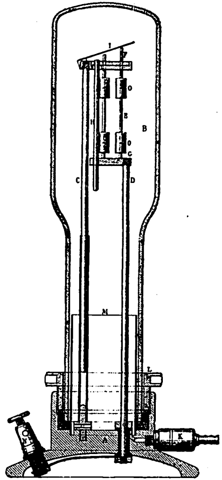

FIG. 46. KONN'S LAMP.

by comparison with gas, each Konn lamp has been valued at about 20 Carcel burners.

The principal cause of the great expense that the use of the light from incandescence entails, rests in the difficulty of preparing small carbons, which cost, as fitted, more than 5 francs per mètre.

A Russian officer, M. Bouliguine, has constructed a lamp (Fig. 47), which attains nearly the same end as that by M. Konn with a single carbon. It consists, like the preceding, of a copper base or socket, two vertical bars, two bars carrying the current, and an exhaust valve.

One of the bars is pierced with a small hole from top to bottom, and has nearly throughout its length a slot admitting the passage of two small lateral lugs.

The carbon is introduced into this bar like the lead of an ordinary pencil-case, and it is assisted to rise by a counterweight connected by two microscopic cables to lugs in the transverse support on which the carbon rests.

The part of the carbon which is to become incandescent is held between the lips of two conical blocks of retort carbon.

A screw placed on the base admits of increasing or diminishing the length of the bar which carries the upper conical block, and consequently of giving to the luminous part greater or less length.

The closing of the globe is effected by the lateral pressure of several india-rubber washers.

When the lamp is placed in circuit, the carbon rod reddens and illuminates until it is about to break. At this moment a small mechanism * commanded by an electro-magnet opens the lips of the carbon-holders, the counterweight above drives out the fragments that would remain in the notch, and the counterweight below raises the carbon rod which penetrates the upper block, and re-establishes the current. The mechanism again acts, but in contrary direction to its first manoeuvre, the carbon-holders contract, and the light is renewed.

* The mechanism in question, which the scale of the engraving will not admit of showing, consists substantially of an iron armature placed in the interior of the lamp, and of two metallic rods acting on two cross levers jointed on to the ring surrounding the carbon-holders.

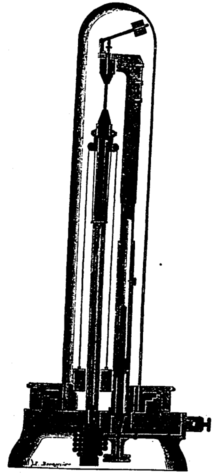

Fig. 47. Bouliguine's Lamp.

We have several times tried this lamp, but we have never obtained good results. It includes too many moving parts, and the least obstacle prevents the play of the mechanism. However, we have observed that when by chance it works regularly, the contacts being better and less numerous than those of Konn's lamp, it needs less intense currents for the production of a given light. With a Gramme machine of 100 burners we have obtained with a single lamp as much as 80 burners, whilst with a Konn lamp we could never exceed 60 burners.

In order to realise the actual value of the system of lighting by incandescence, we have made a series of experiments with several Konn's lamps and a Bunsen battery of 48 elements, of 0·20 mètre height.

The first operation consisted in measuring the resistances of retort carbon of square section. The samples tested were 0·002 mètre in the side. The following results are from eight experiments:

Number of Experiment.	Length of Samples.	Resistance in Mètres of Telegraph Wire.
	mètre.	
1	0·100	16
2	0·100	14
3	0·100	15
4	0·100	14·50
5	0·100	19
6	0·050	7
7	0·050	9
8	0·050	7
Total	.. 0·650	101·50

Whence it results that the mean linear resistance of the retort carbon of 0·002 mètre is about 172, that of a telegraph wire of 0·004 mètre being taken for unity.

We subsequently rounded the carbons, so as to reduce their diameter to 0·0016 mètre, and regulated the length in such a manner as to obtain 0·018 mètre incandescent part. The vacuum was carried to about 0·70 mètre mercurial pressure.

The following results represent the mean of more than twenty series of experiments:

State of the Circuit.	Methods of Coupling the Battery.							
	2 Series parallel of 24 Elements.		3 Series parallel of 16 Elements.		4 Series parallel of 12 Elements.		1 Single Series of 48 Elements in Tension.	
	Galvanometer deflection.	Luminous Intensity of each Lamp.	Galvanometer deflection.	Luminous Intensity of each Lamp.	Galvanometer deflection.	Luminous Intensity of each lamp.	Galvanometer deflection.	Luminous intensity of each lamp.
Circuit closed on itself	47	..	70	..	70	..	50	
5 lamps	28	Reddish-white	17	Cherry-red	10 or 11	Dull-red	·35	½ burner
4 lamps	29	¼ burner	22	Reddish-white	16	Orange-red	38	2½ burners
3 lamps	38	1 to 2 burners	25	½ burner	·26	¼ burner	41	3½ burners
2 lamps	40	3 burners	41 to 42	2½ to 3 burners	40 to 45	3 to 5 burners	44	5 burners
1 lamp	43	4 to 5 burners	·49	11 to 12 burners	60	40 burners	45 to 46	6½ to 7 burners

The lamps were grouped like the elements of a battery in tension, then forming a single series.

In the following table are given the results obtained with lamps arranged in *batteries*, that is to say, on distinct circuits derived from the battery. Because of the considerable differences observed in the intensities of the light of each lamp during the same experiment, we give the total light instead of that produced by each lamp:

State of the Circuit.	Methods of Coupling the Battery.							
	2 Series parallel of 24 Elements.		3 Series parallel of 16 Elements.		4 Series parallel of 12 Elements.		8 Series parallel of 6 Elements.	
	Galvanometer deflection.	Total light emitted by the whole of the lamps.	Galvanometer deflection.	Total light emitted by the whole of the lamps.	Galvanometer deflection.	Total light emitted by the whole of the lamps.	Galvanometer deflection.	Total light emitted by the whole of the lamps.
Circuit closed on itself	54½	..	68	..	69	..	70	..
5 lamps.. ..	57	..	64½	¼ burner	63½	2½ burners	60	..
4 lamps ..	54½	..	63	½ burner	63	3 burners	55	..
3 lamps ..	56	1 burner	61½	2 burners	62	4 burners	58	¼ burner
2 lamps ..	55	5 burners	60	6½ burners	59	15½ burners	55	1½ burner
1 lamp	53½	9 burners	57½	54 burners	55	65 burners	46	6 burners

Several important observations were made during these experiments.

When the receivers are sealed and the contacts carefully put in line, the carbons last for a satisfactory period. The first carbon of a lamp never lasts for less time than a quarter of an hour; sometimes it breaks at the end of thirty to thirty-five minutes, but that is very rarely; its average duration is twenty-one minutes. The succeeding carbons last upon an average for two hours, so long as the luminous intensity does not reach 40 burners, in which case the average duration is only half an hour. In the experiment of four parallel series of 12 elements, the five lamps being collected in batteries and one only lighted, the carbon, which gave 65 burners, lasted only twenty-three minutes as an average.

Attentive examination of incandescent carbons, through a strongly coloured glass, has shown that they are not uniformly brilliant. They present obscure spots, indicative of non-homogeneity, and the position of cracks which rapidly disintegrate the carbon.

The vacuum never being perfect in the receivers, the first carbon is in greater part consumed. It would appear that consequently upon the little oxygen contained in the lamp being transformed into carbonic acid and carbonic oxide, the carbon should be preserved indefinitely. But there is then produced a kind of evaporation which continues to slowly destroy the incandescent rods. This evaporation is besides clearly proved by a pulverent deposit of sublimed carbon, that we have found on the interior surface of the bells, on the several interior parts: rods, contacts, hammers, &c.

No bell has been cracked by heating or cooling during the whole of the experiments, extending over several months, but several of the necks have been broken by the too energetic closing of the joint.

The delicate part of the lamp is in the series of contacts which precede the incandescent rod. The carbons are got into straight line, which is indispensable to their duration, only with minute and long precautions. After rupture, the contact does not always occur automatically, and two or three times we have been obliged to shake the lamp to cause the lighting of the next carbon.

The maximum efficiency has occurred with a single lamp and with four elements in quantity; by employing two lamps and descending to two elements in quantity, the results were considerably diminished.

We have recently made similar trials with Gaudoin artificial carbons of the same section, and the results have been more satisfactory. Thus the total light produced with 48 elements in four series and a single lamp, reached 80 burners, and that produced with the same battery and three lamps, attained 80 burners.

The same battery coupled in tension and actuating a Serrin lamp gives a voltaic arc of 105 burners; but the light obtained by incandescence is much steadier and more agreeable to the eye.

From what precedes, it appears to result that King and Lodyguine's system is much more favourable to large foci than to the divisibility of the electric light; however it is proper to remark that when 10 burners per lamp are not exceeded, the carbons have a very long duration, whilst they are consumed very quickly for an intensity of 60 to 80 burners.

Only carbons of 0·0016 mètre diameter and 0·018 mètre luminous length were until then those tried; these behave very well with a strong current, but give no light with 12 elements. It became interesting to learn what light could be obtained with 12 elements by diminishing the length of the carbons. This was the object of a new series of experiments.

Five different combinations were attempted, by varying in turn the coupling of the battery, the diameter of the carbon and its length.

The best results were obtained with a single lamp furnished with Gaudoin carbons of 0·0016 mètre diameter, and of 0·015 mètre length, in the incandescent portion.

The light varied between 2 and 8 burners, but it was more often 5 burners. Each carbon lasted on average fifteen minutes.

We were about to repeat all these experiments, substituting for the battery a Gramme machine constructed to give the best useful effect; but the imperfections of the lamps, the difficulty of obtaining good contacts, the too minute care to be taken at the commencement of each operation, led us to decide to previously design a lamp more commodious and slightly more practical than that of M. Konn.

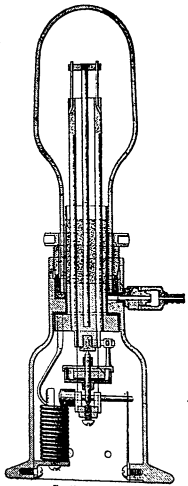

FIG. 48. FONTAINE'S LAMP.

This lamp, which we represent in Fig. 48, is at present under construction by M. Bréguet. It is characterised by the two following points: (1) the carbons are set in a groove at each of their extremities in rigid contacts and kept fixed, which admits of the lamp being placed in all positions; (2) the electric current passes automatically from one carbon to the other by the action of an electro-magnet interposed in the circuit.

A description, even summary, would not be of great interest, since the lamp is not yet finished; the engraving sufficiently indicates the arrangement we have adopted.

CHAPTER XII.

DIVISIBILITY OF THE ELECTRIC LIGHT.

General Remarks on the Divisibility of the Electric Light—Impossibility of establishing very small Luminous Centres with the means actually known—De Changy's Invention—Report of M. Jobart—La cassagne and Thiers' Dividing Regulator—M. le Roux' Experiments—M. de Mersanne's Apparatus—M. Jablochkoff's Experiments at the Magasins du Louvre—A Recent Communication made by M. Denayrouse to the Academy of Sciences.

THE remarkable effects of the voltaic arc were no sooner foreseen than the idea arose of dividing the electric light, and even before the existence of a good regulator for a single light, King took out a patent for a lamp on the divisible system. The steps, however, that were being taken to perfect the single luminous centre had advanced so rapidly, that with an expenditure of 10 horse-power an artificial sun of an intensity of 4000 burners was produced. This grand result was due to the carbons of Foucault, Carré, and Gaudoin; to Serrin's lamps, Gramme's machines, and Sautter and Mangin's projectors. On the other hand, the plan of dividing the light made no advance, but remained still an object of experimental and speculative inquiry.

The merits of the system of King in 1845, and of Jablochkoff in 1877, are of an exceptional character, and it would be a matter of difficulty to decide which of them approaches nearest to the true solution of the difficult problem of dividing the electric light. It must not, however, be thought that in face of these obstacles the idea of replacing gas by electricity will have to be entirely renounced, for science is far from having attained the last of its conquests by means of this mysterious fluid, which has already annihilated distance, and may also be said to have suppressed night; but despite the remarkable labours of M. Jablochkoff, and the no less remarkable initiative of M. Denayrouse, there exists at the present time no sufficiently practical system of so dividing the light as to render it generally available for the purposes for which gas is used. Each decade gives birth to a new idea, the importance of which is exaggerated by rumor until, after a few unsuccessful trials, public interest abates, and nothing more is heard of the matter. In 1847, King's discovery of incandescent carbons was announced in England; in 1857, M. de Changy, in Belgium, substituted platinum for the carbon, and employed a regulator; in 1867, M. Le Roux published in France a method of passing a current alternately, and with great rapidity, through several ordinary regulators; and lastly, M. Jablochkoff, in 1877, caused sparks to pass through plates of kaolin, and by this means obtained a series of small lights.

There is no doubt that each of the systems proposed is capable of rendering important service in special cases, but the error that inventors have fallen into has been the claiming of too great a scope for their apparatus as leading immediately to the supplanting of gas. The electric light has already a vast field of application open to it, and Chapters VII. and VIII. treat of the great advantages attaching to its employment in a number of cases, but that it will some day entirely take the place of gas is extremely improbable. It has, in fact, only been since the introduction of electric lighting that our admiration for the facility with which gas can be divided and distributed has been fairly aroused.

By the term "divisibility of the electric light" we do not mean the production of several intense lights by means of one machine or battery, but simply the maintaining of a few small luminous centres, each equal to 1 to 15 Carcel burners. It has been proved beyond a doubt that several lamps can be kept in action by one magneto-electric machine, but the question is, whether the first cost and maintainance of such apparatus is not greater than that of a series of small machines each in circuit with a lamp. We have always favoured the latter method of lighting, although the other plan has received a large share of our attention, and there is a likelihood that M. Gramme will still have the honor of making it a practical success. At

present, however, the means proposed for attaining this divisibility of the light have been practically without success*.

We will now glance at the various systems devised for the solving of this problem. It has been shown that the invention of King, reinvented by M. Lodyguine, and improved by M. Konn, was better suited to a single light than to a divisible system. There are, however, some advantages connected with the burning of small carbons in a vacuum, inasmuch as the light is steady and the expense moderate. Before abandoning this method, some new experiments should be made with shorter and thinner carbons of various qualities. Where a single lamp and great regularity of the light is needed, this system may come into use. The mode of operation adopted by M. de Changy has never been thoroughly known, but to judge from the following communication made by M. Jobart to the Academy of Sciences on the 27th of February, 1858, M. de Changy's laboratory experiments must have been perfect:

"I hasten to announce to the Academy the important discovery of the dividing of an electric current for lighting purposes. This current from a single source traverses as many wires as may be desired, and gives a series of lights ranging from a night lamp to a lighthouse lamp.

"The luminous arc between two carbons produces, as is well known, a very intense, flickering and costly light. M. de Changy, who is a chemist, mechanician and physicist, is thoroughly conversant with the latest discoveries, and has just solved the problem of dividing the electric light.

"In his laboratory, where he has worked alone for the past six years, I saw a battery of twelve Bunsen elements producing a constant luminous arc between two carbons in a regulator of his own invention, this regulator being the most simple and perfect I have ever seen. A dozen small miner's lamps were also in the circuit, and he could at pleasure light or extinguish either one or the other, or all together, without diminishing or

*This opinion must be taken to refer entirely to the present time, and in no way to prejudge the future; from time to time we have drawn attention to the experiments which have been made in this direction, with a view to the placing of a fair statement before every one who wishes for our opinion on the subject.

increasing the intensity of the light through the extinction of the neighboring lamps. The lamps, which are enclosed in hermetically sealed glass tubes, are intended for the lighting of mines in which there is fire-damp, and for street lamps, which would by this system be all lighted or put out at the same time on the circuits being opened or closed. The light is as white and pure as Gillard's gas, with which it has one point in common, namely, its production by the incandescence of platinum. The gaspipes are replaced by simple wires, and no explosions, bad smells, or fires can take place.

"The trials that have been hitherto made with the object of producing an electric light by means of heated platinum, have failed on account of the melting of the wires. This difficulty has been overcome by M. de Chanzy's dividing regulator. The cost of the light is estimated to be half that of gas. A lamp placed at the masthead of a ship, would form a permanent signal for about six months, without the necessity of changing the platinum. With several such lights placed in tubes of colored glass, it would be easy to telegraph by night, as they could be extinguished and relighted rapidly from the deck. For lighthouse purposes considerable amplitude can be given to the light. I also saw a lamp so arranged in a thick glass globe that it could be immersed to considerable depths without being overturned by any movement. This lamp had already been used in the taking of fish, which were attracted towards the light.

"The above slight description will suffice to show to what a variety of applications this discovery can be put. The communication which I have had the honour of laying before the Academy is founded upon no illusion, a lamp was to my astonishment lit in the hollow of my hand and remained alight after I had put it in my pocket with my handkerchief over it."

It must be borne in mind that the above communication was made by (M. Jobart *, of Brussels) a thoroughly skilled man of

* M. Jobart was born at Bourgogne. He was, at the time this communication was-made, Director of the Royal Museum of Belgium Industry, Chevalier of the Legion of Honor and of the Order of Francis the First of Naples, President of the Society of French Inventors, President of the Nationa Academy of Agricultural and Manufacturing Industry, besides being a Member of the Scientific Institutions of the United States, France, &c.

science, and one not likely to be carried away by the enthusiasm of an inventor.

We have not seen any drawings of the regulator invented by M. de Changy, but we have seen that of MM. Lacassagne and Thiers, patented by them in 1854.

The theory of this apparatus is explained in the following description taken from the patent:

When in any part of the circuit the current has to pass through a liquid of less conductivity than that of the reophores, the intensity or quantity of electricity passing in a given time is inversely proportional to the resistance of the interposed liquid. This resistance may be increased or diminished, either by an increase or decrease of the conducting power of the liquid or of the surface immersed. The magnetic force of an electro-magnet varies with the intensity of the current. If the surfaces of the conductors immersed in the liquid are of an unchangeable metal, we obtain in a free state the gas arising from the decomposition of the liquid; the quantity of this gas in a given time being in direct proportion to the intensity of the current.

MM. Lacassagne and Thiers divided one of the conductors of a battery in action into two parts, attached a plate of platinum to each extremity, and suspended the plates in the interior of a glass gasometer containing acidulated water. The bell of the gasometer was raised or lowered by the inlet or outlet of the gas, produced by the current. The ascent of the bell produced of course a diminution of the galvanic intensity, whilst its descent produced the opposite effect. An electro-magnet, with an armature in the form of a lever and an opposing spring completed the arrangement. The apparatus worked in the following manner:

The spring was first adjusted to the strength of the current determined upon. As long as the magnetic attraction was greater than the tension of the spring, the armature remained in contact, and as the gas which was developed had no outlet, the bell of the gasometer was raised, thereby diminishing the surface of the platinum in contact with the liquid, and consequently the intensity of the current. There would occur a moment of equilibrium and also when the force of the spring exceeded that of the magnet; the armature receded, and in so doing opened a trap which allowed of the escape of a portion of the gas until the normal position of the bell was again obtained. When such a regulator was accurately adjusted, the tap remained constantly partly open, and the armature very close to the electro-magnet without touching it. This regulator, if applied to each of the small lamps of M. de Changy, would prevent the combustion of the platinum wires, but the complication which would arise from this arrangement would render it inapplicable, even if no other practical defects had been found to arise from its use.

MM. de la Rive and Elie Wartmann, both physicists of Geneva, observed that with a very sensitive regulator, and a battery in good working order, a current could be interrupted for the thirtieth of a second without any variation of the arc; but with an interruption of longer duration the arc became enfeebled, and vanished altogether after the current had ceased for the tenth of a second. M. Le Roux, profiting by this observation, has obtained some very beautiful results, which he has thus described in a communication to the Academy of Sciences, dated the 30th of December, 1867:

"The spark from an electric battery is in general incapable of passing between two separated conductors. (A battery of 3,500 elements insulated with the greatest care is necessary for the production of a spark having the length of only a fraction of a millimètre.) The induction currents from magneto-electric machines have a much higher tension, and this accounts for the light produced by alternate-current machines. I have obtained the same effects with a battery of fifty Bunsen elements, and with the current interrupted during the twenty-fifth part of a second, a spark leaped over an interval of about three millimètres. This fact led me to a solution of the problem of divisibility. When a current passes between two conductors, so as to produce a voltaic arc, it has hitherto appeared probable that this passage was due to the elevation of the temperature, and not to the arc itself. The conductibility of the interposed

medium is perhaps only an extension of the fact noted by M. Edouard Becquerel in the case of heated gases, whose conductibility was considerably increased by the enormous elevation of the temperature."

"The carbon electrodes form perhaps a vapor of considerable tension at this high temperature, and this vapor tends to increase the conductibility of the arc." By means of a distributing wheel, revolving with great rapidity, M. Le Roux sent the current of a Bunsen battery alternately into two regulators, in such way that it traversed each of them during the same number of fractions of a second, and he thus succeeded in dividing the light. The lights were under these conditions perfectly equal.

M. de Mersanne, in 1873, took out a patent for the dividing of electric currents on the same principle as that of Le Roux. The mechanical construction of the invention is of so elementary a nature and so little worth patenting that we should have made no mention of it had not M. de Mersanne in the following year made an addition to the patent, which, if not practical, is at least original. The distributing wheel of M. Le Roux he has replaced by a horizontal spindle carrying a series of cams. By means of these cams a reciprocating motion is given to some rollers jointed to vertical metallic arms which are plunged into and withdrawn from cups filled with mercury. When the spindle revolves at a high rate of speed several lamps are put successively into contact with the electric current, whereby a single source of electricity is divided into equal or unequal portions, according to the combination given to the interruptors.

Last year, when traveling through the principal towns of the United States, we endeavored to discover what progress had been made in America in the matter of electric lighting, but we were unable to see anything of a practical nature. Many physicists had been experimenting with a view to the division of the light, but none of them were in a position to show us an apparatus worthy of even being mentioned. We will only refer here to a patent taken out by Mr. Henry Woodward in 1876.

This invention relates to the incandescence of a carbon in a rarefied gas, having the property of not combining chemically with carbon heated to redness.

We have already mentioned the arrangement of parallel carbons forming the candles of M. Jablochkoff and will now give some account of the experiments actually made at the Grands Magasins of the Louvre, and also of the note presented by M. Denayrouse to the Academy of Sciences on the 17th of April, 1877. At the Magasins the object was to increase the light in the Marengo Hall, which was supplied with eleven lustres, and also received light from the halls surrounding it. Around the Marengo Hall, at about two-thirds of the height, there is a gallery on which the electric lights were placed. Two "Alliance" machines worked six candles, and by an ingenious arrangement the candles when burned out were replaced by others, without causing a sensible diminution of the light. The candles were arranged in diffusing globes, and the light was projected forward by means of reflectors. Two sticks of Carré's carbons, 4 mm. in diameter and 12 cm. long, insulated with a thin plate of silicious matter, and fixed in two copper tubes, which were united by a plug of asbestos, formed the candles. A slip of carbon laid across the top of the two carbon sticks served to light them. It was difficult to judge of the intensity of the electric light, as the gas was not entirely extinguished, and the neighboring galleries added their light also, but with a pocket photometer each candle was found to give about 20 to 25 Carcel burners. The irregularities were not great, but of tolerable frequency. A slight and continual flickering was perceptible in all the lights, arising from the nature of the carbons and changes of speed of the motor. An effect of a special kind, which was no doubt due to the ebullition of the silicious substance interposed between the carbons, gave a singing sound to the diffusing globe. We were told that the candles would last three-quarters of an hour; at the Louvre they were renewed every half hour. The advantages of this mode of lighting can only be decided by knowing the cost of machines, motor, &c., the expense of erecting them, and the cost of maintenance per hour for each unit of light. A comparison could then be made with the cost of other existing

electric lights, such as those erected at M. Ménier's chocolate factory at Grenelle.

The labors of M. Jablochkoff have, from a purely scientific point of view, an undoubted value, as he has demonstrated that these voltaic arcs can be maintained in the circuit of a single current, and that two parallel carbons separated by a silicious plate produce a light less intense, it is true, than that of a regulator with ordinary retort carbons, but quite as regular and less intermittent. The possibility of dividing the electric light experimentally, or for purposes of scientific demonstration, was proved by M. Florent at St. Petersburg with Konn's lamp, but the novelty of the newer experiments is that the carbons are burned in the air, and not in a vacuum, as in M. Konn's arrangement.

There is no doubt that M. Jablochkoff, with the active co-operation of M. Denayrouse, will succeed in making the light more economical, and in considerably reducing the large outlay which his system necessitates; but as far as the application of the light to industrial purposes is concerned, the experiment at the Magazine of the Louvre proves nothing whatever. In fact, the only inference to be drawn therefrom is that the cost of this new method of electric lighting is much higher than that of the old system.

The two "Alliance" machines and the six standards for carrying the candles employed in the Jablochkoff arrangement cost at least as much as six Gramme machines and six Serrin lamps. The six candles give 240 Carcel burners*, whereas six Gramme machines with Gaudoin's carbons give 3,000 Carcel burners. Taking, then, the first cost of plant as equal, the system with regulators gives twelve times more light than that with candles.

Taking the horse-power absorbed by the two "Alliance" machines at a minimum, namely, 5 horse-power, two Gramme machines with the same power would produce 1,000 Carcel

* These figures must not be taken as absolute. Our estimate was 20 to 25 Carcel burners, and observations made independently by two other persons gave 22 and 30 Carcel burners. But as it is difficult to take exact measurements, we will reckon 40 burners to one Jablochkoff candle. Even if we double this number, the result of our comparison will not be altered to any appreciable extent.

burners, in place of the 240 burners given by the six Jablochkoff candles. In this respect the advantage is again considerably in favor of lighting by means of regulators. The superiority of the old system is established in the most convincing manner by comparing the consumption of carbons.

An electric candle, costing at least half a franc, lasts half an hour, being at the rate of 1 franc per hour for 40 burners and 12½ francs for 500 burners. With ordinary carbons, the same quantity of light is produced at M. Ménier's for a quarter of a franc; the cost of the candles is therefore fifty times greater than that of regulator carbons. We cannot repeat too often our opinion that M. Jablochkoff will soon succeed in reducing in a certain degree the heavy expenses to which we have just drawn attention.

For instance, the "Alliance" machines are dear, but it is possible to manufacture them at a lower cost, and the candles can also be made more economically. The only fact which we insist upon is, that it is materially impossible to replace advantageously the regulators by candles.

The experiment made at the Grand Magasins of the Louvre was very interesting; it attracted the public, and the journals spoke of it in terms of praise. If not absolutely practical, it yet deserves public attention as being the germ out of which in future a great success may grow. In a word, neither a favorable nor an unfavorable conclusion can be deduced from this experiment, which is perhaps a step towards the solution, but certainly does not satisfactorily solve the problem. The difference of color between the electric light and gas-light was plainly shown, but this difference was also observed some years ago on the Boulevard des Italiens, when M. Tessié du Motay made some experiments with the oxy-hydrogen light.

M. Denagrouse's note to the Academy related to the complete suppressing of the carbon in the production of the electric light. M. Jablochkoff conceived the idea of introducing into the circuit of a magneto-electric machine the primary wire of a series of induction coils; in the secondary wire of each bobbin is placed a plate of kaolin, through which the induction sparks pass. The interposed plate of kaolin gets hot, reddens, and at last becomes

luminous. Around the edge of the plate is placed a priming of a better conducting substance than the kaolin itself. By this arrangement M. Jablochkoff hoped to produce fifty lights with a single magneto-electric machine. The aspirations of MM. King, Lodyguine, Konn, Kosloff, and De Changy were of a like nature, and we wish M. Jablochkoff better success than his predecessors obtained.

Complainant's Exhibit Higgs and Brittle Paper. S. M. H., Exr.

THE INSTITUTION OF CIVIL ENGINEERS.

SEC. I.—MINUTES OF PROCEEDINGS.

JANUARY 22, 1878.

JOHN FREDERIC BATEMAN, F. R. SS. L. & E., President, in the Chair.

No. 1,545.—"Some Recent Improvements in Dynamo-electric Apparatus," by RICHARD WILLIAM HENRY PAGET HIGGS, LL. D., Assoc. Inst. C. E., and JOHN RICHARD BRITTLE, Assoc. Inst. C. E.

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It may be laid down as proved by experience, that for lighting large spaces, not too much subdivided, the advantage is greatly in favour of the electric light; but that where numerous light centres of small intensity are required, or where the space is much subdivided, the advantage is in favour of gas. This advantage will cease when a practical method of subdividing the electric light has been obtained. In places where opaque objects or screens occur that only throw shadow but are not of sufficient size to completely block out the light from the space they inclose, reflectors can be utilized to overcome the difficulty of shadows. When the electric light is capable of minute subdivision it will undoubtedly compete with gas on terms of the highest advantage, since the cost of establishing a gas-works will be many times in excess of that necessary to supply the electric light to a district.

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Complainant's Exhibit, "Telegraphic Journal" Article, for October 15, 1878. S. M. H., Ex'r.

Editorial under heading of "GAS VS. ELECTRIC LIGHTING."

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"It is true that at present an invention, by which "the electric current supplying the electric lamps can "be subdivided so as to feed a great many light centres, and thus at the same time moderate while it distributes the light, is a desideratum necessary to the "complete success of electric lighting even for general "street purposes, let alone household uses. But tried "inventors are at work on the problem, and any day "may see its accomplishment."

Complainant's Exhibit "Thompson's Engineering Letter of Oct. 25, 1878." Feby. 28, 1890. S. M. H., Exr.

"ENGINEERING," VOL. 26, P. 341. LONDON, OCT. 25, 1878

DIVISIBILITY OF THE ELECTRIC LIGHT FROM A DYNAMICAL POINT OF VIEW.

TO THE EDITOR OF "ENGINEERING":

SIR—Much vagueness appears to exist in the minds of men upon the possibility of dividing the electric light indefinitely, and much has recently been said and written upon the question which, if tested by sober reasoning, and by the application of elementary dynamical principles, will be found to be sheer nonsense. The idea that the electric current can be indefinitely subdivided, and the number of small lights indefinitely multiplied, by the employment of a substance more suitable in its conducting properties than carbon, is one that has been freely indulged on many hands during the past fortnight. The reporter of the *New York Sun*, in his enthusiasm to repeat the claims of Mr. Edison, puts into his mouth statements which exhibit the most airy ignorance of the fundamental principles both of electricity and of dynamics. If there be one truth more than another to which scientific credence must be given in the present day, that truth is the dynamical principle of the *conservation of energy*, which asserts that work cannot be done by a force except by the expenditure of a precise equivalent of some other form of energy, actual or potential.

The work done by the steam engine necessitates the expenditure of fuel in the boiler; the light of the gas implies the use of chemical energies stored up in the coal beds; the motion of the telegraphic needle, or of the rotating wheel of the electric pen, involves the consumption of zinc in the battery where the electricity is generated. In a precisely similar manner the heat and light of the voltaic arc—*the* electric light, *par excellence*

—represents a certain equivalent of energy which is transformed into light and heat by the intermediate action of electricity. The battery, or the dynamo-electric machine, with its steam or gas motor, provides a source of energy. The electric current is the convenient method of transferring that energy from the source to the distant point of application. The "strength" of the current is another expression for the rate of transference, and represents the quantity of energy conveyed in a given time.

Let us consider an analogy between this transference of energy by electricity and the transference of energy by the motion of moving bodies. A ball shot from a cannon possesses a certain energy of motion, or "kinetic" energy, by virtue of which it will, when it strikes an obstacle, *do work*, and that of a powerful kind. It has had work done upon it to set it in motion. The principle of the conservation of energy teaches us that just as much energy as must be spent upon it in setting it in motion, just so much will it be capable of exerting by virtue of its motion. The name "force" should accurately be assigned to the rate at which energy is transferred in the act of setting a body in motion. Hence it is inaccurate to speak of the "force" that must be spent upon a cannon ball to set it in motion, we ought to speak of the *energy* that must be expended.

Now, it is one of the stubborn facts of dynamics (though one that hundreds of people refuse to see because they have never examined the question experimentally, or thought it carefully out) that the velocity of a moving body *is not proportional in any simple ratio* to the work that can be done by it, or to the energy that must be imparted to it to give it that velocity. The energy which has been imparted to it, and by virtue of which it can do work, is proportional, not to the simple velocity, but to *the square of the velocity*. An example will illustrate our meaning. Suppose a cannon ball weighing 1 lb. to be shot out of a gun with the velocity of 100 feet per second. A certain quantity of energy in the form of the explosive activities of the gunpowder must be expended on it to give it that velocity; and by virtue of its velocity and weight (which together we call its "momentum") it is capable of doing a certain amount of destructive work. And it will obviously require the explosion of twice as much gunpowder to shoot two such cannon balls at the same rate of 100 ft. per second, and they will do twice as much damage. Now instead of sending *two* cannon balls with a velocity of *100 ft. per second*, let us attempt to send *one* cannon ball at the rate of *200 ft. per second.* Will the same quantity of gunpowder suffice? Will the effective work done be the same? Nothing of the kind. Experience shows that a mass of 1 lb. moving at the rate of 200 ft. per second will do *more than twice as much* damage as the same mass moving with a velocity of 100 ft. per second, *double the weight and you double the destructive energy, exactly*, it is true. But instead, *double the velocity and you increase the destructive energy fourfold.* Treble the velocity while the weight remains the same and you increase the destructive forces ninefold; but then you will require a ninefold charge of powder to produce that trebled velocity. *The effective work done by the moving mass and the energy that must be imparted to it, both increase, therefore, not as the velocity but as the square of the velocity.* The necessity of having a clear idea of this quantity which we term *energy*, by virtue of which work can be done, has been tacitly recognized by physicists ever since Newton spoke of measuring the action of an agent "by the product of its force into its velocity"; where the word force is used for what we now term *momentum* (the product of mass into velocity) the "action of an agent" here expressing the capacity to do work, what has also been termed *vis viva.*

Now in the electric current you have a transfer of energy from the battery to some other point of the circuit. The real source of energy in the battery is the zinc that is oxidized, the energy of its chemical separation being transformed into electricity. If the current does no work on the external circuit, the energy of the current fritters itself away in heating the liquids and

plates of the battery. If the external circuit contains a portion that conducts badly, say a short length of thin plantinum wire, presenting a *resistance* (which we may look at as a species of friction in the movement of the current), then the energy of the current will be transmuted at that point into heat and light instead of being transmuted into heat within the battery. The heat always is developed at that point of the circuit where the resistance is greatest. In the production of the ordinary electric light between two carbon points special care is taken by using stout conductors to avoid all resistance to the circuit except just at the point where intense heat is required. And now, observe, the law of the production of heat from a current of electricity is a law similar to that which expresses the relation between the work done by a projectile and the velocity of the projectile. The heat produced in a conductor of high resistance is proportional not to the simple strength of the current, but is proportional to the square of the strength of the current. This analogy goes even further. Suppose the current to be produced from a single cell whose internal resistance is negligibly small as compared with the external resistance of the circuit. If we link on a second cell we shall double the strength of the current, and shall produce four times as much heat in our wire of high resistance. But mark this: we shall consume four times as much zinc in so doing; for we shall use up twice as much zinc in each of the two cells. Similarly, by linking three cells, we shall treble the current strength, and shall produce nine times as much heat; but we shall use up nine times as much zinc, three times as much in each of the three cells. Now the intensity of the electric light between the carbon points follows precisely the same law. It is proportional, not to the strength of the current, but to the square of the strength of the current. This has been accurately determined by the photometric measurements of Masson, and is also a necessary consequence of dynamics, for the current strength, as indicated by a galvanometer, represents the rate of transfer of energy, and is therefore a fluxional quantity, of which the integral is the energy expended, or its equivalent where it reappears as heat, light, &c.

Now apply these matters to the problem of subdivision of the electric light. Suppose we have a current of a certain strength, which we will reckon as unity. Let us divide that current into two equal parts by dividing the resisting part of the circuit into two branches, whose resistances are equal. A current of half the strength passes through each branch, producing at the point of resistance an effect of heating and illumination. We shall not get in each branch half the light of the previous case; we shall only get a quarter, because the effect follows the square of the current strength. If we had divided the circuit into three branches, in each branch we shall get but one-ninth part of the original light. This diminution becomes serious when we consider a case of large subdivision. Suppose an electric light equal in luminosity to 1000 candles, and we want instead to divide that light into ten smaller lights. If we introduce ten equal branches, each will carry one-tenth part of the original current, and the intensity of light in each will be one one-hundredth part only of the original light, or 10 candles. We shall get 10 lights of 10 candles each, instead of 1 light of 1,000 candles. Clearly it might not pay to subdivide the light at this rate, though it might for particular cases pay to use the undivided current to mass the light in one bright spark of 1,000 candle brilliancy.

Where in place of a battery a dynamo-electric or magneto-electric machine is used in connection with a steam engine or gas engine to generate a current of electricity, the case is a little more involved. It was recently stated by M. Bontemps, of Paris, as the result of his experiments with the Gramme machine, that the strength of current produced by that instrument was directly proportional to the velocity of rotation of the armature. The figures given in Fontaine's "Electric Lighting," on the authority of M. Hagenbach, bear out this statement. But as yet no statistics have been presented on the amounts of fuel used in running the machine at different velocities, and it is not hard to predict that, other things being equal, this quantity will be proportional to the square of the number of revolutions per minute. The arrangement of the dynamo-electric machines, whereby a part of the current is diverted to excite the electro-magnets, introduces an element of difficulty here, since the proportion so diverted varies with the nature of the external circuit, and depends upon its resistance. Whatever Mr. Edison's new discovery may prove to be, it is understood that it refers to a mode of procuring incandescence in a circuit of many branches, and that it does not refer to the question of the source of the current. Yet here, it would on *a priori* grounds appear, lies the most hopeful field for the discovery of a practicable method of distributing the light. As yet we have not the data to enable us to say whether the steam power which now gives us in the dynamo machine a current of great strength, might by any arrangement be as economically employed in giving us one hundred currents of one-tenth the strength each; yet this seems not an improbable view. The recent improvements of M. Jablochkoff in the dynamo machines, whereby each machine generates electricity for four separate circuits, capable of working four "candles" on each circuit, point to a solution in this direction. Happily the question is now in in a fair way to be sifted in the most thorough manner, and even if Mr. Edison's alleged discovery brings us no nearer to a solution of the problem than we had before been, the reckless statements attributed to him in the public press will have done the public the service of showing the true bases upon which the settlement of this great and absorbing scientific problem must depend.

SYLVANUS P. THOMPSON.

Bristol, October 23, 1878.

Complainant's Exhibit "Thompson's Engineering Lecture of Dec. 20-27, 1878," Feby. 28, 1890. S. M. H., Exr.

"ENGINEERING."

Vol. 26, pp. 499-500.

LONDON, Dec. 20, 1878.

THE ELECTRIC LIGHT.

On the evening of the 8th ult., Professor S. P. Thompson, of the University College, Bristol, lectured to a crowded audience at the large Colston Hall, on "The Electric Light." The lecture was extensively illustrated by experiments and photographic diagrams. Mr. Lewis Fry presided, and in his introductory remarks said it seemed probable that the electric light was destined to work a revolution similar to that caused by the introduction of gas. No doubt there were many inconveniences which attended gas, and it might be that the electric light, if it were introduced into their houses would be attended with evils of even greater significance. Possibly Professor Thompson might have a crumb of comfort to give a class of very worthy persons who, he thought, at the present time were in considerable need of consolation; he alluded to the gas shareholders.

Professor Thompson, who was heartily received, then proceeded with his lecture. He said: We are met tonight to discuss a problem of the present age and I want the discussion of that problem to be conducted calmly and dispassionately upon its own merits. We find that in every century there is a great scientific and commercial problem to be faced. Fifty years ago the great scientific problem we had to encounter was whether locomotion should be accomplished by steam power or by horse power. Sixty years ago the great scientific and commercial problem to be faced was whether our houses, our streets and our public places

should be lit with the feeble light derived from burning tallow or oil, or whether we should have gas light. And in this ancient city of Bristol it is known that gas was introduced in the year 1811, or thereabouts, by one whom we ought to honor more than we do, John Breillat, who in his little place in Broadmead set up a gas light; and if he was accused of the unholy work of bringing up fire from below, he convinced the citizens of Bristol that gas could be adopted as a source of light. The problem of to-day is this; is electricity or coal gas to be henceforth our main source of light? Shall our streets, our docks, our ships, our lighthouses, our coal mines, our factories, our workshops, our public halls, our houses and our churches be lighted by the electric light or by gas. It is perfectly right in discussing a problem such as this, a problem which is truly a problem of the age, that the ancient city of Bristol should have a share; and I rejoice that it has a share in the history of electric lighting, for the original discovery of the electric light was due to a philosopher whose name, 80 years ago, made the old Philosophical Institution, now the Bristol Museum and Library famous; a philosopher who enriched our science with several grand discoveries, who showed us why gas flames are luminous, who bestowed on the world several new metals, who gave our miners the safety-lamp—I mean Sir Humphrey Davy, once a Bristol man. In setting forth this problem I propose, first of all, to ask why gas gives light; and secondly, why a current of electricity gives light? After that I propose to give, briefly, a history of electric lighting, showing the various improvements which have been made; then to tell you something about the applications of the electric light and the influence of those applications; and finally, I intend to speak of a new departure which gas has taken recently. In the first place, then, why is it that a flame, such as a gas flame, gives us light? The theory of the luminosity of flame, though it has since received some modifications, was taught originally by Sir Humphrey Davy. Gas gives us light because, in the flame, we have a number of particles which get white hot, and, therefore, become luminous. If I take an ordinary sperm candle and light it, as I now do, I get a small flame. Those who have to study the amount of light which burning substances give, adopt as a standard of lighting a sperm candle which burns 120 grains in one hour. Whenever in the course of my remarks I may refer to the light of a candle, I shall be understood to allude to the light of such a candle as this as the standard candle. The actual cost of 1,000 such sperm candles, burning for one hour, would be about £2. If we burnt enough tallow to give an equal light, we should have to spend £1 3*s*. If instead we used wax candles the cost would be increased £2 15*s*. If, on the other hand, we had burnt 357 cubic feet of gas at 71 No. 5 burners, we should have obtained the light of 1,000 candles at a cost of 1*s*. 2¼*d*., reckoning gas at 3*s*. 4*d*. per 1,000 cubic feet. Paraffine oil at 8½*d*. per gallon would give an equal light at a cost of 5¼*d*. The flame of a candle is a sort of little furnace in which tallow or sperm is burnt, and by the passing of certain solid particles through it light is developed, the particles being heated white hot as they move through it. I do not say these particles are always solid; they may be liquid, or even gaseous, under great pressure; but we find that if a flame be very hot, there being very little solid matter in it, it gives but little light. If I take, say, a spirit lamp in which spirits of wine is burning, I shall get a hotter flame than that of a candle, but it does not give so much light, because there is less solid matter in it. If I take a gas jet and light it I shall find that the light which the jet gives may depend, to some extent upon how the gas is burnt. If burnt in a perfectly ordinary manner, we get a flame which is bright, because there are particles of soot passing through, which are heated and consumed in passing through it. A sooty flame is a bright one. If, however, you mix air with the gas, so that a more perfect combustion is produced, there is no soot produced, and you get a flame with which there is very little light, and is almost non-luminous. But directly you introduce solid matter into the flame you get

a brighter light. (This fact was illustrated by dusting into the flame powered carbon, lime and magnesium; the latter yielding an intensely bright flame). In the case of gas you have a combustion which gives out both heat and light. There is a very considerable amount of heat from a gas lamp. In the electric light you have a light which gives out both heat and light, but there is a very small quantity of heat proportionately, and a great quantity of light. If, therefore, you can get a light in which you have fewer heat rays and more light rays, you may have, other things being equal, a more economical source of light. Perhaps, you will better understand the question by a little analogy. A red hot poker gives out both heat and light, but a great deal of heat and a very little light; 400 red hot pokers in a room would not give out as much light as a sperm candle. In the gas flame we have a good deal of light, but a lot of heat which we do not want. If we can substitute something which shall be as superior as is the flame of a candle to the red hot poker, then, even if the cost be more it may prove a more economical source of light.

I will now go on to speak of the question, how does a current of electricity give light? and here I must at the outset pause to explain a few simple principles of electricity. The electricity by means of which the light is produced is not that electricity which we get when we rub a plate of glass or a stick of sealing wax with silk, and which gives us weak sparks and charges of electricity, but that kind of electricity which is generated in a battery and which travels in currents along conducting wires. There are two sources from which such electric currents may be produced. They may be generated either by a battery or by a magneto-electric (or dynamo-electric) machine. Now here we have a reprerresentation of the simplest form of battery for producing electric currents, a simple cell containing a little acid and water, and into which there are dipped two metallic plates, one of zinc and one of copper. So long as you simply dip them into the acid no electricity is observable, but if a copper wire be led from the copper to the zinc, that wire is traversed by a current of electricity. In other words, electricity passes from the copper or positive pole, to the zinc or negative pole. (The lecturer here threw upon the screen from a magic lantern a photograph of a simple cell and illustrated his remarks as he proceeded). Simple cells of this kind give, however, feeble currents; but it is possible to obtain an increased amount of current by employing more powerful cells, such as those of Grove or Bunsen, and by arranging the cells one after another in a series. Our next picture shows us a battery of four cells so arranged as to obtain a stronger current than is produced by one cell. The wire which passes from the copper or positive pole to the zinc or negative pole carries a current, and by means of that current we can do a number of things. We can telegraph to a distance, or we can produce a light or spark at a distance from the battery. The flow of electricity along a conductor is analogous, in some respects, to the flow of gas along a pipe. It passes from one point to another as if it were liquid flowing along. It, perhaps, is a better analogy, and one which will enable you the better to understand how a solid wire can carry electricity, to compare it with the flow of heat along a hot poker. If you put a poker, or rather one end of it, into the fire and allow it to get hot, the heat travels regularly along the iron from the hot towards the cold end. If electricity is produced at one end of a wire it passes along similarly until it gets to the other end; but while heat travels slowly, electricity travels with lightning speed. We have now a picture—(the photograph was here thrown on the screen)—of twelve such cells employed in producing a spark between two points. These twelve small cells are joined one with the other, the zinc of one to the copper of the next, and the plates of the two end cells are joined by wires to two points of carbon. On making contact between these points of carbon we get a bright light.

If, instead of employing two poles of carbon, you simply join the circuit by a slender wire, the electricity passing along the wire will heat it, if the wire be not

thick enough, for then the electricity has some difficulty in passing along it, and, as the result of the resistance which the thin wire offers it becomes hot. I have here a wire of platinum stretched between two points, and I am going to pass a strong current of electricity through it. The wire, as the electricity passes through it, will get red-hot and will continue to glow so long as the electricity passes. It may get white-hot, and even melt up with the intensity of the heat. If I take an iron wire I expect I shall find a similar result. My iron wire has become red-hot, and is sinking down as it softens in the intolerable glow. I will now take an iron nail and fasten it to the end of the wire coming from the positive pole; when I make it touch the other wire from the negative pole I find I get a bright blaze of sparks; the iron burns away at the point where the current passes through it. When electricity has merely to pass through a small point or a few points you get a tremendous amount of heat developed; the iron fuses and burns, and bright sparks are observed to fly about.

When Sir Humphrey Davy left the old Philosophical Institution in Park street he went to London, and there, in the laboratory of the Royal Institution, he continued the experimental researches which have made him famous. He had there, moreover, larger resources; he had a battery, not of four or twelve little cells, but one of 3,000 cells, to experiment with; and it is whilst experimenting with these cells he found that when the current passed between two points of carbon it gave an intensely brilliant arc of light. We will try and repeat his experiment, although we have not 3,000 cells to experiment with. We will connect with the wires of our battery two poles of carbon. I place them one against the other, and we now produce that electric spark which was discovered by Sir Humphrey Davy. That bright spark of Davy's was the forerunner of all the electric lights that have since been made. The brightness of the spark is due to the intensity of the heat at that point. The more the heat is concentrated at a point the brighter the spark produced. We have in the cellar below a battery, not of 3,000, but of 60 cells. To give you an idea of the way in which this battery is arranged, our next picture will show you the arrangement adopted in the Opera House at Paris, where the electric light was first used during the opera of "Le Prophete," in 1846, to produce artificial effects on the stage. Now let me show you, on a magnified scale on the screen, the image of those two carbon poles. I make the carbons touch one another, and then draw them apart. That lovely blue flame which plays between them is the so-called electric arc formed by the current. While the current of electricity passes from one carbon pole to the other, the carbons get white hot, and it is found that they actually burn away. It is also found that one burns away faster than the other because there is an actual transference of matter from the positive to the negative carbon. The electricity in passing from one pole to the other carries with it some little particles of carbon; one pole, therefore, is constantly receiving an addition of little particles which are taken from the other. To produce a steady light, therefore, requires an arrangement which shall regulate the distance between the poles, bringing them nearer together as they burn away, and bringing up faster that pole which burns away the more rapidly of the two. This necessary "regulator" is usually a complicated piece of clockwork furnished with two clamps to hold the carbon rods, and so adjusted as to keep the points always at a right distance from the centre. Here we have a regulator of just such a kind as is necessary to produce a steady electric arc; having here the two poles of carbon, and the means of raising and lowering them, whilst the points are kept by the clockwork at a right distance apart. But it requires to be very carefully adjusted in order to produce a perfect result. This regulator, invented by M. Duboscq, of Paris, contains an ingenious device, by means of which any cessation of the electric current, consequent on the carbon points becoming too far from each other, acts on an electro-magnet, and causes it to release the wheels of the train, which forthwith brings the carbon points together

and then separates them to the requisite distance. You will observe the arrangements of the regulator in the diagram now thrown upon the screen; and here we have also a diagram of the somewhat similar regulator of Serrin, which is usually constructed to hold very large carbons, and particularly adapted for application to light-houses. Another regulator, that of Foucault, which I am this evening going to use, is of a more complicated pattern, and is so intricate in its parts that it requires to be as carefully treated as a watch. If it gets out of order it requires to be sent to a specially skilled mechanic who understands it making. (The electric light regulated by the last mentioned apparatus, was now shown, and lit up the hall with great brilliance. Its power was very penetrating and for a moment almost dazzling.) Now I should like you to notice what intensely sharp shadows are cast. Even the shadow of water can be seen. (The lecturer poured out a glass of water opposite the light, and the shadows appeared perfectly opaque. The same fact was most successfully illustrated by the shadow of the flame of a candle cast upon the wall.) Now the sharpness of this shadow is not always very convenient. It is a consequence of the light being concentrated at a bright point. It is very dazzling and very unpleasant to look at. The light was tried some time ago in some large spinning mills, in Normandy, but very soon afterwards gas lighting was returned to; the reason alleged was that the workmen had a difficulty in distinguishing the shadows from the threads so intensely sharp were the former. This is indeed but one of a number of inconveniences that must be obviated before the electric light, as I have just shown to you, can be generally adopted. It serves admirably for light-houses, where you want a splendid bright blaze, and it has been adopted also for certain scenic effects on the stage; it has also been employed in the magic lantern, having been known for this purpose in physical laboratories for many years.

Now I ought to tell you that in thus producing the electric light in the manner known to us for thirty years, there are three great inconveniences. The first of these is that it requires a battery, in which you dissolve metals in corrosive acids, which requires skilled labor to keep it in order, and which throws off nasty fumes. The light requires in the second place an expensive clockwork regulator very liable to get out of order; and thirdly, the light is too bright unless it can be split up into a number of smaller lights. The difficulty of subdivision is the chief difficulty in its wide appplication. You cannot divide the light without losing a considerable proportion. If you divide it into two you do not get so much as half the light at each place, and two regulators of this pattern will not work together; one puts the other out.

Now these three drawbacks to the electric light have been met by three discoveries of modern date. In the first place, a battery with acids, such as I have described, is no longer necessary; in the second, a complicated regulator is no longer necessary; and in the third it is found to be possible under certain circumstance to subdivide the light. Before, however, we turn to modern improvements let me mention the cost of producing the light by a battery and regulator. The prime cost of such a regulator and a battery of sixty cells cannot be less than £50. And the cost of acids and other material used cannot with the greatest economy be reckoned at less than 3s. 8½d. per hour, per thousand candles light. At Her Majesty's Opera the cost was found to be about £2 per night. A more serious item, however, than the cost of material in maintaining the current is the labor it demands. The old system of a battery of cells and the regulator required skilled labor at every turn; the new systems do not require skilled labor to such an extent, and therefore while they may be more costly in other respects they may for the purpose of industrial application be more economical. It is a point that I want you to distinctly bear in mind, that apart from the intrinsic costliness of the light, its economy may after all be a question of economy in the employment of skilled labor.

Faraday made the great discovery that currents of electricity could be obtained from magnetism. He found that whenever a conducting wire and a magnet were made to approach one another a momentary current of electricity was thereby induced in the wire. This is the principle of the modern magneto-electric machines; and as it is of the utmost importance, I wish to illustrate the fact to you by actual experiment. We now throw on to the screen the image of an instrument known as an galvanometer, whose purpose is to detect and measure the strength of an electric current. In the arrangement as I have it here (Fig. 1) you observe a scale divided into degrees and an upright pointer. That upright pointer is attached to a small magnet suspended on light pivots within a coil of wire. If a current of electricity travels through the coil of wire of the galvanometer the motion of the galvanometer needle will be clearly seen by the motion of its shadow over the scale. The coil of wire which I hold in my hand is joined to the galvanometer, and at my side here is a very powerful magnet. Following Farraday's discovery I suddenly place the coil upon the magnet, and you observe the impulse given to the index of our galvanometer as the result of the induced current. When I remove the coil of wire we shall have another current induced, but the impulse will be in the opposite direction. I pull away the coil, and, see, the galvanometer needle is sent flying round with the current thereby induced.

This principle was early turned to advantage in the magneto-electrical machines of Saxton, Holmes, Wilde and others. Probably you are already familiar with them in one form. Here is a little machine, such as may be found in the shop of almost any optician, and its object, as you well know, is to give people electric shocks. There is a magnet of steel, and in front of the poles of that magnet a pair of coils of wire are rotated upon an axis by turning a handle. The ends of that rotating coil of wire are placed in connection with the two handles which you hold, and the unpleasantness of the effect to the person who holds the handles is largely due to the fact that the shocks are not continuous. The induced currents are in one direction as the coils approach the magnet poles, and in the opposite direction as they recede; so that the shocks are sent very rapidly through the person first in one direction then in the other. In the large magneto-electric machines used in electro-plating and for the electric light it is, however, usual to add a commutator to the apparatus, which has the effect of sending the currents in the same direction. One machine on this principle, very successful in its day, though cumbrous and weak beside the more modern patterns, is the "Alliance" machine of which we have here a photographic figure. In it 96 coils of wire were rotated upon an axis between 48 steel magnets. Such machines were successfully employed in conjunction with a Serrin regulator for producing the electric light both in France and in England. More powerful machines were produced when electro-magnets were employed instead of magnets of hard steel; and the suggestion that the whole or part of the generated current might be employed in exciting the electro magnet was made almost simultaneously by Siemens and Varley. Such machines are more powerful than those in which only steel magnets were used; and they have received the name of dynamo-electric machines. Like the large magneto-electric machines they require to be driven by a powerful engine. Another stage of improvement was reached about eight years ago, when M. Gramme devised an armature in the form of an iron ring, which he caused to rotate between the poles of the electro-magnet; when the currents induced in the coils of wire wound upon the ring were collected by a suitable commutator, continuous currents were obtained.

The earlier forms of Gramme's machine are in their general arrangements not unlike the little machine for giving shocks which I showed you just now having the ring armature rotating between the poles of a horse-shoe magnet. The most recent Gramme machines are somewhat different, and the picture now before us represents the compact little machine

used so largely in Paris. It has two straight electro-magnets above and below the rotating axis, and the rotating ring lies in between them. The entire machine stands a little over 3 feet high, is about 2 feet long, and with its stand weighs 400 pounds. With a two horse-power engine to drive, it may be driven at a rate of nearly 1000 revolutions per minute. Another very successful dynamo-electric machine, and one which competes fairly with the Gramme machine, is that of Dr. Siemens, of London, who long ago attacked the problem of generating electricity on a large scale from a magnet. The peculiarity of the Siemens machine, as you will see by our picture of it, is the longitudinal coil of wire that is rotated in the middle between the electro-magnets. It requires a high speed of revolution and is liable to get hot, but has produced some splendid results. Other dynamo-electric machines are coming into use, and we have already the system of M. Lontin in operation in London. Our American cousins speak very highly of two other dynamo-electric machines of which I am sorry we in England know little but the names. They are called from their inventors the Brush machine and the Farmer-Wallace machine.

The great advantage of these dynamo-electric machines over batteries is not so much that they are free from the objections attaching to corrosive acids or unpleasant fumes, but that they furnish, after the first expenditure of capital, a larger quantity of electricity for the same cost. In fact, the cost of producing electric currents of any required power is now simply the cost of buying a dynamo-machine and a steam engine, and of the coal and labor necessary to supply and attend to them.

The second inconvenience of the electric light, namely, that it necessitated the employment of an expensive and delicate "regulator," has been met quite recently by the discovery of simpler and cheaper substitutes. The arrangement I shall first describe was devised about four years ago by a Russian inventor who bears the name of Jablochkoff. His invention, which has already almost revolutionized electric lighting, is of the following nature. Instead of placing the two carbon pencils end to end, as in a regulator, he places them side by side at about a sixth part of an inch apart, and the space between them is occupied by a strip of kaolin, or, in the latest forms, of plaster of paris. This arrangement is commonly known as the Jablochkoff electric candle, and we shall see that its behavior justifies its name. Our figure (Fig. 2) shows the "candle" set in its appropriate holder. The electricity which arrives from the dynamo-machine passes up one carbon, crosses the slice of intervening plaster at the top and descends the other carbon on its return to the negative pole of the generator. The arc, therefore, has its place at the top of the "candle,' in the place where the flame of an ordinary candle is. Both the carbon tops become intensely luminous, and the intervening plaster fuses and glows. It melts away as the carbons waste downwards, and the candle is therefore slowly consumed away "just like a candle." Here, however, M. Jablochkoff had a difficulty to contend with. The carbons waste at unequal rates, the positive carbon being consumed nearly twice as fast as the negative. The first attempt to remedy the defect by having a positive carbon of twice the thickness of the negative did not meet with practical success. M. Jablochkoff therefore devised a machine which should produce, like the early magneto-electro machine, not a continuous current, but a series of alternate currents following one another with great rapidity. A commutator on this principle reversing the current 6,400 times a minute can be applied to the Gramme machine. M. Gramme has also constructed for M. Jablochkoff a distributer giving alternating currents, and, at the same time, dividing the current out to several separate lamps or systems of lamps Using this system of rapidly alternating currents the "candles," when made with purified artificial carbons of great density, burn steadily and evenly until they are consumed away. Each is about nine inches long. They cost about 7 1/2d. each, but, probably, can now be made at a lower price, and each lasts about an hour and a half. I am told that a certain gentleman, whose

knowledge of electrical matters was not very extensive, when he heard that the electric candles cost 7 1/2d. each, ordered a gross of them, expecting to be able to burn them in an ordinary candlestick. I need hardly remark that that individual was greatly disappointed. The Jablochkoff candle is, after all, only a means of obtaining the luminous arc from a current already obtained in a dynamo-electric machine.

Now, let me explain the system for distributing the current to the "candles," as adopted pretty uniformly in Paris. The Avenue of the Opera at Paris is lit by 46 electric lamps, each lamp being contained within a globe of opal glass, supported on a lofty standard. The light that fills each globe with a lustre like that of a full moon is the light of a Jablochkoff candle. If each "candle" lasts an hour and a half only, it is obvious that more then one candle will be wanted in an evening. Four "candles" in appropriate holders are, therefore, placed in each opal globe used for the light, and matters are so arranged that when one candle has burnt away another can be turned on. In the Avenue of the Opera at night you may observe a man going round about every hour and stopping at each lamp to turn on a new candle. In the lower part of the diagram we have two machines. The little Gramme machine to generate a current in the left hand, and on its right, and worked by a band from the same motor, the distributor, an invention of M. Jablockkoff, which serves the double purpose of rendering the current alternating, and of distributing the induced currents into four or more curcuits. By this means M. Jablochkoff can work sixteen candles with one steam engine of 18 horse-power, the lights being arranged in four series of four lamps each. We may, therefore, say that up to this point M. Jablochkoff has solved the problem of dividing the electric light. Now, I have had the good fortune to obtain an actual "candle." I have placed that candle upon an appropriate stand within a globe of opal glass, and I will pass a current of my battery through it. If we succeed in lighting our candle, we shall, however, be able to enjoy its light for a short time only, for since the current from our battery passes through it in one direction only, it will consume unequally, and the arc will eventually grow too long to be sustained by the current.

The Jablochkoff candle has already stood the test of practical application. For sixteen months it has been in regular use in the Hotel and Magasin du Louvre. In that enormous establishment they have now eighty candles burning. They are arranged in five groups of sixteen candles each. Each group of sixteen candles costs the establishment £2 11s. a night; but each group replaces about 250 gas burners which previously cost the establishment £3 12s. 3d. per night. So that for two-thirds the cost they get nearly three times the light. For all that we cannot regard the invention as perfect. The light of each candle is not as bright as the same current would produce in a regulator, and the opal globes, though they reduce the unendurable brilliancy of the naked arc to that magnificent glow, cut off, on the best estimates, at least half the light.

At the present moment several rival inventions are in the field. The printing office of the *Times* newspaper is now lit by a lamp, the invention of another Russian of the name of Rapieff. The peculiarity of this lamp consists in the production of the arc between four carbons arranged in two V-shaped pairs meeting at a point. The regulator is very simple, and allows one of the carbons to be replaced without putting out the light. It is said to give a very steady illumination. Another lamp, even more simple in structure, has come to us from the United States. This is the Wallace lamp. It consists, and I have a rough model of it here to show you, of a couple of flat plates of carbon placed one above the other, edge to edge, with an intervening space about the eighth of an inch. When once started by the contact of the carbons the arc passes from the lower carbon to the upper, and as the edge consumes away it travels along to a fresh place. The plates are held in an appropriate frame, which can be hung up any where. I now light the lamp, and you will at once be struck by one disadvantage, the dark shadow cast by the plates themselves and by the frame. Nevertheless, the durability, simplicity, and cheapness of the arrangement, show that it is really a valuable substitute for the regulator, and a formidable rival to the Jablochkoff candle.

And now we must turn to the third of the disadvantages attending the electric light, its extreme and dazzling brilliancy, and consider some of the suggestions that have been made for reducing it to more manageable and endurable proportions. The problem of dividing the electric light is an old one. So far back as 1847 a patent was taken out in England for producing a light by passing the electric current through a thin rod of carbon, which it heated to redness, like those wires with which we experimented. The system so long ago initiated has recently been revived in England by Mr. Werdermann, of whose lamp you may have recently read in the papers. The light is not brilliant, but perfectly steady, and admits of subdivision to a certain extent. Mr. Werdermann's own statistics show, however, that subdivision is only accomplished at a great sacrifice. Using a two-horse-power engine, he tells us he obtained with two lights a power of 320 candles in each, or of 640 candles in total. But when distributed to ten lights, the same current gave a brilliancy of 40 candles at each point, or 400 as a total. This is no advance on the results obtained by King, in 1847. Another attempt was made in 1858, when M. Jobart announced to the French Academie that M. Chauzy had solved the problem of subdividing the electric light. The small lamp of M. Chauzy consisted of a glass globe enclosing an incandescent spiral of platinum, and small enough to go into the pocket. It was even let down on one occasion into the water to attract the fish at night.

Now, we have heard a great deal of late of Mr. Edison and his discovery of a means of indefinitely subdividing the light. I do not know how far Mr. Edison's invention fulfills the promise of its announcement; but I do know that the accounts of it in the American press, which have been copied into English papers, have been grossly exaggerated. Men of eminent scientific reputation, who have seen Mr. Edison's light, and whose word I have every reason to trust, tell us that it is a beautiful scientific toy—nothing more. Happily we have now an inkling of the nature of the discovery for the *Scientific American* has raised the veil and told us what Mr. Edison's electric light is. If we are to accept that statement, it consists in passing a current of electricity through a small coil of platinum wire, or some such contrivance, which becomes white hot, and then, to prevent the wire being quite fused away by the force of the current when the heat becomes too great, the expansion of a metallic plug or bar diverts a portion of the current. He, therefore, obtains the light not by an electric arc but by incandescence. We do not yet know the details, but to give you an idea as best I can of what I mean I have fixed in a frame here seven little spirals of platinum wire at some distance from each other. They become white hot when the current passes through them, and were my current to become too strong one or more of them would be melted up I am here sending the whole current at my disposal through these seven spirals, and I put it to you whether we get as much light from these seven spirals as from our arc between carbon poles. I cannot tell you what Mr. Edison's particular method of distributing the current to the spirals may be, but this I can tell you, as the result of all experience, that any system of lighting depending on incandescence will utterly fail, from an economic point of view, and will be the more uneconomical the more the light is subdivided.

Nextly, I have a few photographs to throw upon the screen in illustration of some of the applications of the electric light; but before exhibiting these I feel inclined to show you a photograph of Mr. Edison. Mr. Edison, whose face is not as familiar to us as his name, is a very remarkable man. He has made some wonderful inventions, for to him we owe not only the electric pen and the phonograph, but also duplex and quadruplex systems of telegraphy, and a host of other beautiful things. When he invents, however, he does not

talk, and when he talks I am afraid he does not invent. He told us recently, through the reporter of the *New York Sun*, and I only hope that the reporter made it all up, that the same wire which brought you the electric light would bring you heat or motive power enough to work a sewing machine. But when we spend heat and motive power to produce our electric currents (and know of no cheaper way of producing them), do you imagine that we shall get out of our electricity more heat or more motive power than we put into it? Before Mr. Edison's portrait fades from our memory, let us put beside it a portrait of Sir Humphrey Davy, who, as the original discoverer of the electric light, must be regarded as no less worthy of fame. Time does not permit us to give more than a hasty glance at the varied applications of the electric light which the remaining views of my series illustrate. I have told you of the application of the light in Paris to the lighting of streets and of the great Magazin du Louvre. But it is also very extensively employed for illuminating workshops and factories. The chocolate factory of M. Menier in Paris and I am happy to think that we do not know as much about French chocolate in Bristol as unhappily we know about French sugar, and two other factories belonging to the same proprietor, have long been lit by means of Serrin's lamps. The electric light has also been used in two of the railway stations in Paris; it has been employed very successfully at La Havre in the construction of the new docks and harbor there; and it has done good service amid the darkness of mines and quarries. It provides an absolutely safe safety-lamp to the coal miner, as it may be completely enclosed in glass, and requires no supply of air. It has been successfully employed in fishing; for the fish come to look at the light and so are caught. And the suggestion has been made, though I do not know whether it has actually been carried out, that divers should carry down the light with them when descending to examine a wreck. I have already mentioned the great success with which the light has been introduced into lighthouses, and for the lighting up docks and harbors. I am sure you will agree with me that if we had the electric light for illuminating the windings of our River Avon, we should be far less likely to have a recurrence of those unfortunate accidents which have made our river notorious. We have lately heard, too, of a novel application of the electric light, and of foot-ball matches played by the light of its beams. I am told, however, that the peculiar sharpness of the shadows cast has sometimes caused awkward mishaps, the players occasionally kicking at the shadow of the foot ball, in mistake for the ball itself. But there is one direction that I have not yet alluded to, in which the introduction of the electric light promises to be of great value. In those industries in which colors of materials are concerned a pure *white* light is of the utmost value. We know that we cannot judge of colors by gaslight; but under the electric beams colors are the same as by day. There is yet another result to be obtained from the electric light. You cannot photograph by gaslight, because the visible violet rays and the invisible chemical rays by which the sensitive film is affected are absent from the rays of gaslight. But the electric light possesses them as daylight does; and therefore photographs such as this beautiful specimen which I hold in my hand can be taken by the electric light. And now I have a little curiosity to show you. The white face of this clock is made of a phosphorescent substance which has the property of taking in the light in the daytime and giving it out afterwards at night. But it it not affected by the yellow glare of gaslight. It has been kept in the dark all to-day, and you see it does not shine. I allow the light of this big Sugg burner to fall on it, and still it does not shine. I now hold it for a brief half minute to the rays of the electric light, and it shines as it would have done with sunlight. The phosphorescence of such substance has been known for thirty years, but this clock is a rather novel application of the old discovery.

We have now compared the relative advantages of the electric light and of lighting by gas from most

points of view, and we have taken a glance at the relative costliness of each method of illumination. The former gives us splendid concentration of light at a distinctly cheaper rate than could be obtained by the consumption of coal gas. But the loss in subdivision is so great that for domestic purposes the use of electricity is accompanied by such an extravagant expense as not to permit of its becoming general. I do not say that the electric light will never supplant gas for domestic purposes; he would be bold who would venture to assert that anything is impossible in science; but I do say that, so far as the present state of science warrants us in pronouncing a judgment, electric lighting for domestic purposes will not pay. And I doubt whether it will pay to light our houses and passages and offices by electricity until we have discovered a cheaper source of electricity than that which is at present the cheapest, viz., a dynamo-electric machine driven by a steam engine.

And now comes a matter which is of some importance perhaps to some amongst you. If we admit that the electric light is cheaper than gas when employed on a large scale, and agree to use it for lighting our lighthouses, our docks, our ships, and the squares and larger streets of our cities, how will the holders of gas shares be affected by the change? What amount of the value of their property will have gone into the air? I have gone into the question carefully, because I do not want it to be misunderstood. Let me give you the statistics first of the largest gas company in the world—the Gas Light and Coke Company of London—and afterwards those of our own Bristol United Gas Company. I take the figures from the last half-year's balance sheet of each; and I find that in the case of the Gas Light and Coke Company, out of a gross revenue of more than a million pounds, the receipts from the sale of gas and rentals of meters amounted to £909,-863. The sale of coke and other residual products produced £239,865. For street lamps and public lighting the company received £65,080, which is not quite 6 per per cent. of the gross receipts, and must have been the least profitable part, since £11,008 had to be paid back for the expenses of lighting and repairing the public lamps. Only 5 per cent. of the net receipts of that company then are derived from public lighting, the remaining 95 per cent. coming from private consumption. The introduction of the electric light for the illumination of squares and streets would, therefore, relieve the gas shareholders of the least profitable 5 per cent. of their takings, leaving them the most profitable 95 per cent. Taking the figures of the Bristol United Gas Company, we find that it has a paid-up capital of £321,250, and that during the last half year its total gross receipts amounted to £73,501. of that amount the rent of meters and private sale of gas yielded £51,360, and the sale of residual products realized £14,672. Only £7,249 or about 10 per cent. of the gross receipts were derived from the public lamps, a percentage which is reduced to 6¾ by the repayment of £2,008 for lighting and repairing the public lamps. In this case, therefore, the gas shareholders, if it came to the worst, would simply be relieved of that 6¾ per cent. of their takings which pays them worst, and which they get the least thanks for. I am not, indeed, quite sure that they would be losers thereby, for people would not be contented with dull lights indoors and would probably burn more gas. In the face of these figures I must confess that it is difficult to comprehend the extraordinary depreciation that has taken place in the shares of the gas companies. In the accompanying diagram (Fig. 3) you will observe how the value of the shares of the two companies whose position we have been studying are graphically depicted. In the earlier parts of the year the values of the £100 shares were quoted pretty steadily at £190 to £200. They fell in August when vacation sightseers in Paris sent over such glowing news of the electric light, and they fell again with extraordinary suddenness in October at the bare announcement that Mr. Edison had invented a method of indefinitely subdividing the light. And now, in the beginning of November we find the shares which a year ago were worth

£200 worth only £140 or £150, and all because it seems likely that the companies must in the distant future contemplate giving up the worst paying 5 or 6 per cent. of their business. But I beg you not to forget that coal gas is a child of science not yet fully grown, and to it also science promises a future of developed usefulness. We hear continually of a new departure for gas, of new and economical gas stoves, of new gas burners like this splendid triple burner of Mr. Sugg, which almost rivals the electric light, and of new gas engines, which for many purposes are more economical than steam engines. There is, indeed, every reason to believe that there is a future before gaslight as before the electric light, and that while the electric light may serve some purposes best, there will be other purposes best served by gas. And doubtless the future of gas will in some measure be determined by the use of better burners and the manufacture of a better and cheaper gas, and also by a more prompt attention on the part of the gas companies to the requirements of the public.

One word more and I have done. Remember that gas lighting was, in its time, as much a scientific discovery as is the electric light. Why should we not be as proud of one great discovery as of the other? I hold that science promises a future of developed usefulness not to electricity alone, but also to gas. And if I have succeeded in putting the questions at issue in this rivalry between these two children of science in a light intelligible not to gas shareholders alone but to the intelligent citizens of a free city, I shall rejoice that it has fallen to my lot thus to labor for the material progress of a great community and for the intellectual development of the age.

Complainants Exhibit "B" Morton Lecture Upon the Electric Light" Jany 2 1879

LECTURE UPON THE ELECTRIC LIGHT.

Delivered Oct. 17, 1878, Before the American Gas Light Association.
By Prof. HENRY MORTON, Ph.D.,
Pres. Stevens Inst., Hoboken, N. J.

Gentlemen of the Gas-Light Association: I purpose this evening to show you what the electric light now is in the various forms in which it has been developed up to the present time, and also to give some account of its history, and to point out, from a study of the latter, what are the reasonable prospects of its future development.

In the first place, evidently as electric light is some source of light developed by electricity, and as there are three distinct methods by which electricity may be caused to develop light, we have naturally three distinct sorts of electric light.

Naming these in the order of their intensity, they are:

The Electric Arc,
Ignited Conductors,
Incandescent Gases.

These I will show you and explain in their order.

THE ELECTRIC ARC.

Fig. 1.

The electric arc may be said to have made its first appearance on this planet in the laboratory of the Royal Institution, in London, when Sir Humphrey Davy, in 1808, made his famous experiments with the galvanic battery of two thousand pairs of plates, with which he decomposed soda, potash, etc., and discovered their metallic bases.

The experiments of Davy were repeated and extended by various continental investigators, and in this country by the elder Siliman, of Yale, who first noticed and described many of the characteristic phenomena of this electric discharge, or "Voltaic arc," as it is called.

Its image was first projected on a screen by Foucault, and "electric lamps" or regulators were, at an early period, devised by him, by Deleuil, by Duboscq, and by many others; and efforts to improve these in the way of rendering them more efficient in producing a reliable and steady light, have continued down to the present day, and are by no means at an end now.

In order to understand these, it will be necessary to consider a little what this "electric light," "electric arc," or "electric discharge," is, or consists in.

When two pieces of dense charcoal, retort carbon, or the like, are connected each with one pole of a galvanic battery, consisting of fifty or more pairs of plates powerfully excited, and, after being brought into close contact, are slightly separated, a stream of electric fluid, as we call it, rushes from the positive to the negative pole, carrying with it particles of the carbon, as well as filling the space between with vapor of the same. The particles thus torn off are exceedingly heated by this action, as are also both the poles between which they fly, so that all become intensely luminous. The intensely hot and luminous poles constitute the "electric light" of this form.

I now cause the image of the electric arc to be projected upon the screen, and you there see (Fig. 1) what I have described. If we place a piece of silver in a carbon cup, arranged as the positive pole, then, as you see, the electric fluid into a luminous white bright globule, from which springs a tongue of emerald green flame, and also a cloud of silver smoke, or vapor and silver, forming a swaying curtain of vapor around the brightly luminous globule and negative pole of carbon.

Beautiful and intense as is this electric arc, it is evident that, in order to become useful, it must be rendered constant and uniform in its action.

Now, to render this electric arc in any degree constant and reliable, a variety of conditions must be provided for.

Thus, in the first place, as I have already noticed, a part of the carbon is actually vaporized. This causes a wearing away of the poles. Again, the carrying of particles of carbon from one pole to another changes the form of each. If the action goes on in the air, there will also be an actual combustion of the carbon poles. To counteract these sources of irregularity regulators of various sorts, operated by clock work or by gravity, and controlled by the current and the consumption of the carbons, have been devised by Duboscq, by Foucault, by Gaiffe, by Serrin, by Siemens, and many others.

The difficulty with all these, in fact, is, however well they may regulate everything else, they cannot regulate the minute accidental variations in the structure of the carbon poles during their consumption, by reason of which these sometimes become very uneven about their extremities, which

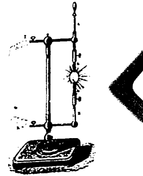

Fig. 2.

diminishes the amount of light produced, and at others change their shape so as to allow the main discharge to pass more to one side than another, so shifting the source of light from side to side of the poles, the side furthest from the discharge always emitting much less light, and being shaded by the pole itself from the greater light produced on the other side.

Thus, for example, with an electric arc springing, as shown in the cut Fig. 2, from the left side of the poles, a b, many times as much light will be emitted towards the left as will come towards the right, and as the arc flies around, this direction of maximum of emission will, of course, change with it.

So immense are the fluctuations produced in this way that, in the experiments which I have myself made, I found the same light, measured from a given direction, to change, within a few minutes, back and forth between 400 and 2,000 candles.

The use of reflectors and shades tends to equalize these irregularities, but they are present to a marked degree in all arrangements which have ever come under the notice of the present writer, notwithstanding the contrary assertions of all their respective inventors or promoters. Thus, only a few days after I had first noticed the electric lights used in the basement hall of the Equitable Building, and had remarked their exceptional irregularity, I saw in one of our mechanical journals a long article on the very regulator there used, describing it as the successful solution of the problem of a perfectly steady electric light. Again, a few days since I was visited, within a few hours, by one of the prominent promoters of electric lights, who described to me the universal satisfaction expressed by every one with his regulators; and by one of our largest mill owners, who was anxious to introduce electric lights into his mills, but having examined the same light in a place where a number were in constant use, found that that regulator, at all events, was entirely too unsteady to answer.

All things, of course, have their degrees, and there are undoubtedly numberless places where the best regulators are quite steady enough to do all that is required. But certainly the problem of an electric light steady enough for all uses has not approached a solution in the direction of what are known as "electric light regulators."

Many years ago elaborate experiments were made to overcome the difficulty by employing a stream of mercury, falling in successive drops from one reservoir to another, as the source of the electric light. This was known as the Way light, and extensive experiments, with massive and costly apparatus, were carried on to test its efficiency. The volatilization and oxidation of the mercury, the want of constancy in the light, and other like causes, however, led to the abandonment of these experiments, after a large sum had been expended.

To dispense with the costly machinery of these mechanical regulators, M. Jablochkoff has recently carried out the ingenious plan of making a sort of electric candle, in which two parallel rods of carbon, separated by a narrow band of fusible porcelain, are supported vertically and made the poles of an electric circuit. The current, leaping between their ends, melts down the barrier of porcelain as the rods are consumed, and thus the "candle" burns down. This arrangement has, without doubt, the merit of simplicity, but it has found little favor in this country, because it has proved to be less reliable than the "mechanical lamps" or "regulators," and to involve a great waste of power, expended in overcoming the resistance of the interposed porcelain.

In this department of electric lighting, the case stands, I believe, at the present day thus:—Improvements in electro motors (that is, machines for producing electricity, of which we shall speak further on) have given us relatively cheap electricity, obtainable with convenience wherever steam power is at hand; but the electric light regulators of to-day are not essentially different from, or much in advance of those of fifty years ago, and, while they will furnish a light reliable enough and steady enough for a vast number of uses, they are by no means fit for universal application, nor does the progress which they have made in the direction of improved steadiness hold out any strong encouragement to hope that much more can be done in this direction, unless some radically different method can be discovered.

The questions of economy, efficiency, and practical application of the "electric arc," as a source of illumination, as well as the proper basis of measurement by which to determine its actual performance, I will discuss farther on after we have considered other departments of the subject which must be included in such consideration.

We will turn now, therefore, to the next form of electric light—that mainly produced by

INCANDESCENT CONDUCTORS.

In some of the early experiments of Sir Humphrey Davy, we find mention of the heating to luminosity of wires of various metals, as tests of the comparative power of different batteries; and, in 1858, so great an advance had been made in the practical utilization of this means of lighting, that M. Jobart, in a report to the Academy of Sciences in Paris, was able to speak as follows:

"I hasten to announce to the Academy the important discovery of the dividing of an electric current for lighting purposes. This current, from a single source, traverses as many wires as may be desired, and gives a series of light ranging from a night lamp to a lighthouse lamp.

"The luminous arc between the carbons produces, as is well known, a very intense, flickering, and costly light. M. de Changy, who is a chemist, mechanician, and physicist, is thoroughly conversant with the latest discoveries, and has just solved the problem of dividing the electric light.

"In his laboratory, where he has worked alone for the past six years, I saw a battery of twelve Bunsen elements producing a constant luminous arc between two carbons, in a regulator of his own invention—this regulator being the most simple and perfect I have ever seen. A dozen small miner's lamps were also in the circuit, and he could, at pleasure, light or extinguish either one or the other, or all together, without diminishing or increasing the intensity of the light through the extinction of the neighboring lamps. The lamps, which are enclosed in hermetically-sealed glass tubes, are intended for the lighting of mines in which there is fire damp, and for the street lamps, which would by this system be all lighted or put out at the same time, on the circuits being opened or closed. The light is as white and pure as that of gas, with which it has one point in common, namely, its production by the incandescence of platinum. The gas pipes are replaced by simple wires, and no explosions, bad smells, or fires can take place.

"The trials that have been hitherto made, with the object of producing an electric light by means of heated platinum, have failed on account of the melting of the wires. This difficulty has been overcome by M. de Changy's breaking regulator. The cost of the light is estimated to be half that of gas. A lamp placed at the mast head of a ship would form a permanent signal for about six months without the necessity of changing the platinum. With several such lights, placed in tubes of colored glass, it would be easy to telegraph by night, as they would be extinguished and relighted rapidly from the deck.

"For lighthouse purposes considerable amplitude can be given to the light. I also saw a lamp so arranged, in a thick glass globe, that it could be immersed to considerable depths without being extinguished by any movement. This lamp has already been used in the taking of fish, which were attracted towards the light.

"The above slight description will suffice to show to what a variety of applications this discovery can be put. The communication which I have had the honor of laying before the Academy is founded upon no illusion; a lamp was, to my astonishment, lit in the hollow of my hand, and remained alight after I had put it in my pocket with my handkerchief over it."

In looking the matter up in the *Comptes Rendus*, or minutes of the French Academy, I find that the communication of M. Jobart was received at the meeting held March 1st, 1858, and was referred to M. Becquerel. At the meeting of April 5th, M. Becquerel reported that he did not find anything sufficiently definite to warrant the Academy to express an opinion as to the importance of this discovery. "All that was desirable at present was fuller information." At the meeting of April 19th, M. Jobart responds to this request by stating that "he could not give more precise details without exposing the author to see another profit by his discovery."

Familiar as is the fact that history repeats itself, we cannot but be struck by the many points of resemblance between the above and what we read in the newspapers of to-day, concerning the wonderful doings of Menlo Park, and must hope that Mr. Edison's inventions will escape that permanent obscuration which seems to have finally shrouded M. de Changy's.

It would appear as if this brilliant and complete success described by Mr. Jobart as achieved by M. de Changy in Paris, in February, 1858, was very rapidly followed up in this country, for I learn from a letter in the Salem *Observer* of Nov. 2, 1868, that Mr. Moses G. Farmer, at some friend of his in Salem, lit their parlor for every evening during July of 1859 with electric lamps operated on a like principle.

It is true that nineteen years have not sufficed to render this admirable arrangement successful in practice, but what is that to the prophetic mind which, foreseeing what is to happen in the "near future," naturally overleaps distinctions between past and future, theory and practice.

For us, however, who only know the past and the present, it may be well to look a little closer at the means actually used, and the results obtained, in these and other experiments.

In the first place, let me show you what this light by incandescence actually is.

There is a coil of platinum wire, through which I pass the current from a battery. It grows first red, then yellow, then white, and now it gives out a beautiful soft and steady light; but we must be cautious, if I allow the current to become a little stronger, the wire fuses and drops asunder, and our experiment is at an end.

It is, as I understand, just here that Mr. Edison has made his much announced but carefully concealed invention. He has devised some simple and ingenious arrangement by which the solid conductor can be brought up to the highest point of incandescence, without risk of fusion.

True, this achievement was claimed for M. de Changy, and seems to be implied in Mr. Farmer's description; but somehow, as with the famous perpetual motion machine, "the little screw which makes it all go" does not appear to have been forthcoming in either case, and in this present year of 1878 we still look to the "future," "near" or remote, for the "practical success" so confidently announced nineteen or twenty years ago.

The first electric lamp operating by incandescence of which we have any actual record seems to be that invented by the American, Starr, a patent for which was taken out in England by his agent, King, in 1845, and which has thus come to be known as the King lamp. This lamp has been modified in details until it has reached the form shown in Fig. 3, known as the Konn lamp.

This apparatus consists of a glass vessel provided with a metal cap and packing box below, by means of which it can be closed air-tight.

A connector at K allows of the exhaustion of air from the interior, and the filling of the interior with any inactive gas.

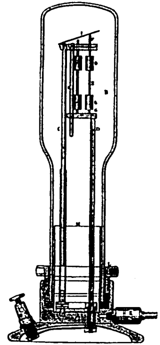

Fig. 3.

Two upright metallic conductors, connected respectively with the two poles of the electric circuit, pass up through this glass vessel and at their upper ends support, as shown, two or more rods of carbon or other conductors. The electric connection with these rods is made from C by means of the lever I, which communicates first with the longest rod, F, and when that is burned up, falls upon the next longest, and so on. The light is produced by the rod of carbon heated white hot by the current.

Various slight modifications of this lamp have been made and elaborately experimented with; but they all show the same essential characteristics. The first of these is that, as long as any oxygen remains in the vessel, the carbon rods consume rapidly, the first one generally lasting only twenty minutes. The second carbon will, however, last two hours if the light does not exceed forty burners; but even when all active gas has been removed, the carbon suffers a sort of vaporization.

The second characteristic of these incandescent lamps is that, with the same current, they develop much less light than is obtained from the electric arc. Thus, a battery of 48 elements, with a Serrin lamp, gave an electric arc equal to 100 burners; but with one of these lamps gave a light equal only to 30 burners, and when divided between three lamps, gave only the light of 10 burners each.

The third characteristic is the manner in which the light-producing power of the current diminishes as it is distributed between a number of lamps. Thus, the current from a given battery, acting on one lamp, produced a light between 4 and 5 burners; on two lamps, a light of 1½ burners each; on three lamps, one-third to two-thirds of a burner each. From another battery, the current on a single lamp gave a light of 11 to 12 burners; with two lamps, one-half burner each; and on three lamps, one-ninth of a burner each.

In another case a given battery with one lamp gave the light of 9 burners: with two lamps, 3½ burners; and with three lamps, one-third of a burner each. Another battery with one lamp gave a light of 66 burners; with two lamps, 7½ burners; with three lamps, 1½ burners; with four lamps, three-fourths of a burner; and with five lamps, one-half burner each.

In this connection it is curious to notice that the latest accounts from Mr. Edison show that he gets a light equal to about 48 candles, or three argand gas burners, per horse power with his new device, and with similar machines for producing the electric current and the electric arc, from 1,000 to 2,000 candles per horse power; thus showing remarkable agreement with these earlier experiments as to the loss of effect resulting from the subdivision of the light.

Another modification of this Starr or Konn lamp is found in that which has been recently exhibited in New York as the Sawyer-Mann lamp.

This differs from the former apparatus in no important feature except that the interior of the vessel is said to be filled with pure nitrogen at the ordinary pressure. The carbon rods are said not to waste away in these lamps. Without knowing anything positively on the subject, my opinion is that this is only because they have not been subjected to strong currents, but have only been heated to the extent of yielding the light of one or two burners. Under these circumstances, the carbons of the Konn lamp will last a long time, but on the other hand, the light so obtained is not economical, as we see above.

When exhibited in New York recently, we understand that five lamps only were operated by a magneto machine of Arnoux & Hochhausen, driven by a three-horse power steam engine, said to be developing only one and one-half horse power.

It is certain that none of these lamps have yet demonstrated anything like such practical success as can enable us to see that they can take the place of gas in ordinary illumination. They have, of course, many advantages in certain respects over the electric arc, but these are combined with compensating drawbacks on the part of economy; and it is only by turning our eyes to the as yet *unrevealed possibilities of the future* that we are able to see the electric light *as a successful substitute for gas and other methods of illumination.*

Another method of electric illumination by ignition is that suggested by Jablochkoff some time since, but which seems to have been abandoned practically on account of the costliness of the apparatus, not to mention other difficulties.

This consists in causing the main current to pass in a series of interrupted or reversed pulses through the primary circuits of numerous induction coils, and then to pass the induced sparks, obtained from the secondary coils of these instruments, across or around little rods of porcelain, which thus become heated to whiteness.

Fully to understand this it will, however, be necessary to explain the structure and operation of an "induction coil," and this comes naturally now in order in connection with the third method of obtaining light from electricity, namely,

ELECTRIC LIGHT FROM INCANDESCENT GAS.

In order to obtain electricity in such a state that it will pass through a gas and thus heat it to luminosity, we must, in practice, make use of an induction coil.

One of these instruments is shown in Fig. 4, as seen outside, and in section in Fig 5; its structure and mode of operation may be described as follows:

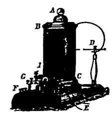

Fig. 4.

Beginning from the interior of the structure we have in the first place a core A B, formed of a bundle of soft iron wires. This is surrounded by a

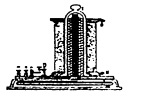

Fig. 5.

[illegible] thick copper wire so arranged that an intermittent current of electricity from a galvanic battery may be passed through it. The interruption is effected as follows. The current from the battery enters at the bind[ing] screw and passes by a brass strip to the column C and thence to the [bra]ss spring, which rests against the screw D, thence by the column D into [the co]il imbedded in cotton around A B, and out again to the battery by the [bindi]ng screw. When the current is to be interrupted, a hammer, omitted [in] the figure, falls upon the spring between C and D, so striking it away [fro]m the screw D. When the current passes, it powerfully magnetizes the [cor]e and when it ceases, the core rapidly (we may say instantly) loses its [mag]netic properties.

[Out]side of this coil thus carrying the battery current, and which is known [as] the "primary coil," or "primary circuit," is another coil, F F, usually [of] very fine copper wire of great length, varying from hundreds of feet to [hun]dreds of miles in different instruments. This is known as the "second[ary] coil," or "secondary circuit," and in it is produced, by magneto-dy[nami]c induction, a momentary current at the instant when the iron wires of [the c]ore become magnetic, and another momentary current in an opposite [dire]ction at the moment when the core loses its magnetism. The gaining [and] losing of magnetism is, of course, the result of the passing and stop[pin]g of the primary current, and thus, in this sense, the secondary or in[duc]ed current is caused by the primary one. If in place of simply inter[rup]ting the primary current, as above, rapidly alternating currents, in op[pos]ite directions, are sent through the primary coil, the practical result will [b]e the same. These momentary induced or secondary currents have as we [s]ay, high intensity, being able to leap over distances and pass through re[si]sting materials.

Thus the coil shown in Fig. 6, constructed some years ago for the present writer, and which contains, in the outer or secondary coil, 50 miles of wire, will throw a spark 21 inches through air, or through a block of solid glass

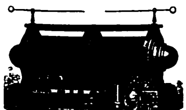

Fig. 6.

three inches thick. These instruments are, however, on account of the amount of wire used, and the careful insulation needed, very expensive. Thus the one shown in Fig. 4 cost $375, and that shown in Fig. 6 $1000. To employ one of them wherever a single gas burner was to be replaced would, therefore, be out of the question on this ground of cost, without considering any other objection.

This same discharge from an induction coil may also be used as a source of light in another way.

If an exhausted vessel, or one only containing highly rarefied gas, is arranged with conductors running into it, as in Fig. 7, and these conductors are connected by wires with the ends of the secondary of an induction coil, then the electricity will pass through the rarefied gas, producing light which will be often arranged in strata, or layers, in the manner indicated in the drawing, Fig. 7.

If the cross section of the vessel is smaller, the light is brighter, and thus, by the use of tubes with wire let into them, very brilliant effects can be produced. Such tubes are called, from their first manufacturer, a glass blower of Bonn, Geissler tubes, and some of the ordinary forms are shown in Fig. 8.

By using different gases, and employing various fluorescent substances, in the surrounding jackets, very beautiful combinations of colored lights are obtained.

I now show you a number of these tubes arranged on a screen, and illuminated at once by the discharge from my large coil.

Some of these tubes you will notice not only emit a bright light while the electric discharge is passing, but continue to glow for some minutes after it has ceased. This introduces us to a new phenomenon of light.

Fig. 7.

When light falls upon certain bodies its vibrations cause changes in the relative positions of their particles, somewhat like the changes which heat vibrations produce in solids when they cause them to melt, for example, ice melted by the sun's rays. When, however, these vibrations cease to act, the changed substance falls back into its previous condition (as when the melted ice again congeals), but in so doing, emits again vibrations like those expended in the former change, but of lower "pitch," or greater wave-length. Just as water in freezing emits heat, of low "pitch," and thus cold, compared with our bodies, but nevertheless heat compared with

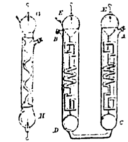

Fig. 8.

a zero of temperature. So these phosphorescent bodies exposed to strong light suffer a change which, in reversing itself, causes the emission of light again, fainter, it is true, and lower in "pitch," that is, of a color nearer the red or lower end of the spectrum, than the exciting light, but nevertheless very appreciable light. Thus violet light, by phosphorescence, becomes blue, green, yellow, or red; blue light becomes green, yellow, or red, and so on.

Such gases as are contained in these tubes are, however, not alone in possessing this property. I have here several solid substances—sulphides of barium, strontium, and calcium—which behave in the same way. We illuminate them by an electric spark, and then they continue to glow in the dark. Superior to them all, however, I find the dial of this clock.

I expose it for a moment to the electric light, and now you see it in the dark from the farthest corner of the hall.

I have analyzed the material with which this clock dial is coated, and I find that it is a sulphide of calcium ("Canton's phosphorus," discovered in 1768), attached by some resinous medium or varnish. Though the substance is therefore in composition, only the old and familiar one above mentioned, its present manufacturers have found out some method of wonderfully increasing its efficiency. One of these clocks exposed for a moment to direct sunlight glows so brightly as to be easily seen in a room which is darkened. This phosphorescence is, moreover, readily excited by lamp or gas light, and one of these clocks will continue to glow during an entire night with no other excitement than that which it gets by the diffused light in a room during the day. Toward morning the glow is faint, but is still sufficient to show the position of the clock hands.

The substances required to make this compound—i. e., lime and sul-

... are very cheap, and the French savant, Becquerel, who has elaborately investigated this subject, describes methods of preparing it so that it will emit light of various colors—orange, green, blue, and violet. If a further advance in brilliancy and duration should be made at all equal to that shown by the clock dials as compared with all former specimens, it is not improbable that this may become a very important substance. If we could paint our walls with such a body it would, as it were, absorb light during the day and then emit it during the night, and it would only be necessary to have curtains to draw over our luminous walls at night to shut off their light when necessary, just as we now draw curtains over our windows in the daytime.

In face of such an arrangement as this, even Mr. Edison's new "electric [illegible]" would be costly and unnecessary. By painting the outside of houses with the same material, all need of street lamps would be avoided. It is true that "some practical difficulties remain to be overcome," but what are these in these days of inventive power? Should one of our great inventors take the matter in hand and organize a stock company, it will, of course, be merely a question of time and expense in preliminary experiments. Seriously, however, this new form of phosphorescent sulphide of calcium is a wonderful substance, which may well suggest strange possibilities for the future.

[illegible]

In whatever way electricity is to be used as a source of light, there is, of course, no question that a cheap source must be found in order that it may compete with other sources of illumination. As long as the galvanic battery was the only source of electricity, we were met at the very start by the following state of facts.

forces are distributed in certain directions, known as "lines of force." Some notion of these is obtained if we place a plate of glass over a magnet and then sprinkle iron filings on the former, when on tapping the glass the filings will arrange themselves in certain lines.

A very beautiful method of arranging and permanently fixing such lines has been devised by Prof. A. M. Mayer, and from a plate so arranged by him Fig. 9 has been produced by a process of photographic engraving.

Now it was discovered by Faraday, in effect, that whenever a conductor was so moved in the vicinity of a magnet as to pass through or "cut" these lines of force, a current was developed in the conductor. The greatest effect was obtained when the lines were cut at right angles, and when the greatest number of lines are cut in the same time, either by passing through a denser "field of force" as near the poles of the magnet, or by moving more rapidly. When the conductor moved along the lines of force no current was produced.

As the conductor passed into and through the "field" of one pole a current was developed in one direction, and as it passed out of the same field into and through the field of the other pole, a current in the opposite direction was developed. Between the two fields there would, of course, be a neutral point where no current was developed. Indeed, if we turn to Fig. 9 we will see that a conductor, while passing the centre of the magnet, would be moving along the lines of force, and ought, therefore, to develop no current, while near the poles it would pass at right angles to the lines of force, and so give a maximum current. At other parts of its path the conductor develops currents of more or less intensity, according as it finds the lines of force more or less oblique to its path.

While the above [illegible] of explanation is very commonly employed in connection with our present subject, it does not seem to me as satisfactory,

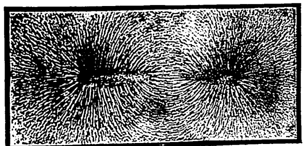

Fig. 9.

The source of energy in the battery is practically the zinc consumed. Weight for weight, coal has almost six times the available energy of zinc; while, moreover, the price of zinc is about 25 times that of coal. In the race between the two, therefore, zinc starts with this enormous disadvantage that an equal amount of energy obtained from it will cost about 150 times as much as if obtained from coal. To make gas from coal, and burn it for light will then be cheaper than to obtain electricity from zinc and turn it into light, unless the loss in the former case is 150 times greater than in the latter.

Batteries, therefore, as sources of electric force for lighting purposes, are out of the question from an economic standpoint.

The possibility of economic lighting by electricity came first to exist when, in 1831, Faraday discovered that the motion of a magnet in relation to a conductor would develop a current of electricity in the latter, and thus that electricity might be developed by the expenditure of mere mechanical energy.

Then, to the coal distilled in the retort was born as a rival (as yet helpless as an infant and unknown), the coal burned under the boiler of the steam engine.

This child has grown slowly or rapidly ever since, and if the reign of the *gas coal* is to end, it will be only to its near relation, the *steam coal*, that it will yield its throne.

It is therefore eminently proper that we should trace the progress of this development in the present connection.

The first principle involved in this subject is this:-

Magnets exert forces in all directions around them, but in such a way that they may be said to be surrounded by "fields of force," in which the

ner as clear and direct in its relations to the entire subject of electrical induction, as another which I shall now proceed to state.

In the first place, it will be desirable to state the relations between magnets and electric currents first pointed out by Ampere.

According to this theory, a magnet owes its characteristic properties to the presence in the molecules of electric currents all circulating in the same direction.

In other words, if Fig. 10 is supposed to represent a short magnetic bar with its south end toward us, the little arrows would represent the direction in which the currents of positive electricity were flowing in its molecules.

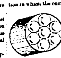

Fig. 10.

Fig. 11.

Fig. 12.

The general effect of such currents could evidently be expressed by single currents passing in the entire bar, as indicated in Fig. 11, and the practical effect of such a series of parallel currents would very evidently coincide with that of a current passing through a helix, as indicated in Fig. 12.

As a matter of fact, we find that a helix of wire, through which an electric current is flowing, will exhibit all the properties characteristic of a magnet. Thus, it will attract iron, if freely suspended point north and

...ath, and if two of such helices are brought together their like ends will repel and their unlike ends attract each other.

The attraction and repulsion, moreover, appears to come under a still wider law, for it may be readily shown that any parallel electric currents, flowing the same way attract, and if going opposite ways repel.

Fig. 13.

Fig. 13 shows how this explains the attraction of unlike and repulsion of like poles in magnets.

In A and B, the north and south poles being opposite, the magnetic or electric currents flow parallel and in the same direction, and thus attract. In A and B, the two north poles being together, the currents flow in opposite directions, and thus repel.

Another general law must next be stated, namely: Whenever a conductor approaches a parallel current, a momentary flow of electricity is established in the said conductor, opposite in direction to that of the current towards which it is moving; as the same conductor recedes from the current a momentary flow in an opposite direction is produced.

Let us see how this applies to such a case as we have now to consider.

Let NS, Fig. 14, represent a magnet in which the magnetic currents are flowing as indicated by the arrows on the bar; if, then, we bring a conductor, like the loop of wire to the right, towards the south end of this magnet, a current will be developed in the loop opposite to the currents in the

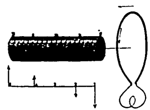

Fig. 14.

magnet, because the loop is approaching all of them. If now the loop continues to be moved forward over the S end of the magnet, when it comes over, say the point n, it will still be approaching many of the magnetic currents, but will be receding from a few, those, namely, which it has already passed. There will, therefore, be an interference between the opposite currents due to the approach to the magnetic currents to the left, and the recession from those to the right, and the resulting current will, therefore, be feeble, although still in the first direction.

When, however, the loop comes over m the number of magnetic currents it is leaving is just equal to that of those it is approaching, and the two currents will, therefore be exactly neutralized.

Beyond m, towards N, however, the current due to the withdrawal from the magnetic currents will predominate and increase until the North end of the magnet is passed.

The horizontal lines with vertical arrows, at the lower part of *Fig.* 14, represent the directions and relative intensities of the currents developed as the loop moves over the magnet from right to left.

It will be readily understood that it is quite immaterial whether the conductor is moved over the magnet or the magnet is moved through the conductor.

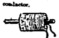

Fig. 15.

Thus, if the conductor is wound into a coil, as in *Fig.* 15, and the magnet is pushed into or drawn out of it, we shall have a like production of currents.

Or again, if the coil should have in its centre a bar of soft iron, and this should be magnetized by the approach of a magnet, and then lose its magnetism on the withdrawal of the same, this will be equivalent in effect to the sudden insertion and withdrawal of a magnet.

The first attempt which was made to utilize the above-described principle in producing a current of electricity from a magnet by the expenditure of mechanical energy was that by Pixii, of Paris, who, in 1832, produced the apparatus shown in *Fig.* 16.

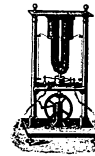

Fig. 16.

Here two coils of wire, with soft iron cores, are supported at the upper part of a frame, while below them a strong steel magnet is made to rotate by appropriate machinery. As each pole of the magnet in turn comes opposite the iron core of either coil, it renders it instantly magnetic, and thus develops a current in the surrounding coil. These currents of course are alternately in opposite directions, and to correct this a "communicator" is placed below on the moving shaft, which, by reversing the connections at the right moment, sends the currents always in the same direction through the exterior wire.

Saxton, in Philadelphia, made, in 1833, a modified form in which the steel magnets were placed horizontally, and remained at rest while the coils with their soft iron cores were rotated opposite their ends. Various small modifications followed. Thus, in 1836, Clarke, in London, made a machine represented in *Fig.* 17, in which the steel magnet was made of several single

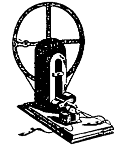

Fig. 17.

magnets united, and the coils were rotated opposite the poles, but at right angles with the plane of the magnets.

Again, Breton wound coils on the poles of the magnet, and then rotated an armature in front. This armature, by its approach and withdrawal, caused movements in the lines of force, or in the magnetic currents which developed momentary currents of electricity in the coils of wire. The relation of this action to Breguet's apparatus for exploding mines, and to the Bell telephone, is worthy of notice.

Duchenne combined this last plan with the preceding one by winding coils both on the magnet and the armature, and using one or other of the circuits for his induced current.

[To be continued.]

LECTURE UPON THE ELECTRIC LIGHT.

Delivered Oct. 17, 1878, Before the American Gas Light Association,

By Prof. HENRY MORTON, Ph.D.,

Pres. Stevens Inst., Hoboken, N. J.

(Continued from page 7.)

The first attempt to make a magneto-electric machine of such a size as to be available for industrial purposes, was made in 1849, by M. Nollet, Professor of Physics at the Military School at Brussels.

The original intention of those first engaged in developing this machine was not, however, to produce with it an electric light, but to employ it to decompose water so as to the that the *hydrogen so liberated might be used as an agent of illumination*. If we were in want of an illustration of the extravagance and irrationality of expectation which so often exhibits itself in enterprises entering upon new fields, we surely need go no further than this. M. Nollet died before his designs were entirely carried out, but they were elaborated by an intelligent workman who had assisted him in the construction of his machines, M. Joseph Van Malderen, who, under the auspices of a company composed of French and English capitalists, and named the "Alliance Company," developed the apparatus into an efficient generator of electric currents for the direct production of light by means of the electric arc.

The apparatus, as thus constructed, was, in general principle, only an enlargement of the Clarke machine (already shown), and consisted of a large number of compound steel magnets, between the adjacent poles of which cores of soft iron, surrounded with coils of insulated wires, were made to revolve. An appropriate connection of these various coils with each other, and with commutators on the axis, enables the current to be taken off in a constant direction. When it was afterwards discovered that, for an electric light, the current need not be constant in direction, but was even more convenient when rapidly alternating, this was of course yet more easily provided for. Fig. 18 shows one of these Alliance machines, which really

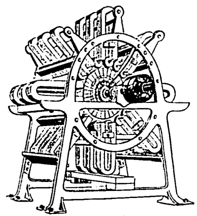

Fig. 18.

needs no further description, but is rendered perfectly clear in its structure and operation by the cut.

Many of these "Alliance machines" were made and used in different places in France for lighting works of construction at night, such as the Cherbourg docks, and on some vessels as the Lafayette and the Jerome Napoleon, and in some lighthouses; and, as modified slightly in arrangement of parts by Mr. Holmes, in England, notably in the South Foreland lighthouse.

The great cost of these machines, the large amount of power required to run them, and the cost and trouble of keeping them in repair, however, limited their use to a very narrow field, and they could hardly be said to have carried the subject of electric lighting beyond the range of an interesting scientific experiment on a large scale.

The next important step in the development of the magneto-electric machine consists in the application, by Dr. Siemens, of his peculiar armature to these instruments.

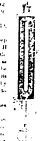

Fig. 19.

This armature is shown in longitudinal section in Fig. 19, at E, and in cross section at F.

The armature is in fact a rod or bar of soft iron, with deep grooves cut lengthwise along it, reducing its section to an H form, as is shown in F. Insulated wire is then wound lengthwise in these grooves, as shown in E. Such an armature as this, provided with caps, as shown in Fig. 19, may then be rotated in a very narrow and dense magnetic field, and its wires will cut many lines of magnetic force in a short time by reason of their rapidity of angular movement, being close to the axis of rotation.

This armature was first used in magneto-electric machines employed for telegraphing by Siemens, in 1857.

The next advance, and this a very marked one, was made in 1866, by H. Wilde, of Manchester, who, on April 11, communicated to the Royal Society the result of a series of experiments with magneto-electric machines, of which Fig. 20 is a good representative.

In this machine a number of small horseshoe magnets are so arranged that a Siemens' armature may be rotated between their poles. The coils on this armature have developed in them, by moving in this highly concentrated magnetic field, a very powerful current. This current is then passed through heavy coils of wire surrounding the sides of a large U magnet, made of massive plates of wrought iron. Between the poles of this rotates another Siemens' armature of larger size, from which a current of immense power is obtained.

While the electric current developed by this machine far exceeded anything which had ever been obtained before, it was only secured by a large expenditure of power: something between a five and a twenty horse power engine being required to drive it.

The important fact developed by Mr. Wilde in this machine was that a magneto-electric machine could develop a current whose magnetizing power

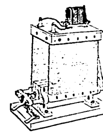

Fig. 20.

was vastly greater than that of the magnets from which it was derived. Thus, if the small magnets above would lift a weight of 50 pounds, the large electro-magnet below, when excited through their instrumentality, would lift 500 pounds or more. This possibility of a sort of magnetic accumulation or growth was a demonstration of immense value to the progress of magneto-electric science.

A practical difficulty which first showed itself in a conspicuous degree in these very powerful machines was the heating of the armature. Foucault had first shown, long before, that when a conductor was rotated or moved in a magnetic field it became strongly heated.

The apparatus to illustrate this is shown in Fig. 21, where a copper disc is rotated between the poles of a powerful magnet, and becomes very hot.

Tyndall, by similarly rotating a copper tube, melted the fusible metal with which it had been filled.

The heat developed in the armatures of Wilde's large machines was so great as to cause serious inconvenience, and of course involved a great loss of effect or waste of power.

In 1867 Siemens proposed a very obvious modification of the machine of Wilde, by dispensing with the smaller machine and connecting the coils of the large one with its own armature through the commutator of the same.

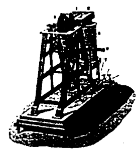

Fig. 21.

The residual magnetism of the iron of the electro-magnet was found sufficient to start the action, which then increased by self-development.

This, however, occasioned what was at first regarded as a serious difficulty.

If the magnetism of the electro-magnet was thus made to depend on the current of the machine itself, any interruption in the flow of the same in the exterior circuit at once cut down or destroyed this magnetism, and so reduced the whole action.

To obviate this, Ladd, of London, first made a machine with an armature wound with two coils of wire, one being connected with the magnet of the machine, and the other with the exterior circuit.

Afterward he made a machine in the form shown in *Fig.* 22, where two armatures were used—one connected with the coils of the machine itself, and thus supplying what is often called the "field of force," the other supplying the exterior circuit.

Subsequent experiment has, however, shown that the arrangement is very far from economical in the conversion of energy, and all the machines now in use include the exterior circuit and the field of force in one continuous connection.

This, of course, greatly complicates the relations, and makes the fluctuations during running greater and more numerous; but for the sake of

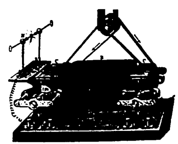

Fig. 22.

efficiency or the economy of expended power, it has been found essential to adopt this arrangement.

PACINOTTI'S RING MACHINE.

The first magneto-electric machine for the production of an electric current continuous in character and constant in direction and intensity, was that devised by Dr. Antonio Pacinotti, in 1860, and constructed by him for the physical and technological cabinet of the University of Pisa. A description of it, however, did not appear till several years later in the June, 1864, number of the Italian scientific periodical, "Il Nuovo Cimento." This number, which was published during the month of March, 1865, contained an extended illustrated description of the machine.

As a special feature of the apparatus he pointed out the peculiar form of the movable electro-magnet—a circular iron ring in which, contrary to the

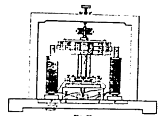

Fig. 23.

case with the armatures previously in use, the magnetic poles did not remain stationary, but could be moved within the ring—that is, made to assume in it successively all possible different positions.

This movable ring of iron had the shape of a spur wheel of 16 teeth, and was firmly secured to the axis of the machine by means of four strips of brass. Small wooden wedges were placed upon the teeth of the ring, and the space so formed between each two of the wedges filled up regularly with insulated copper wire. These spools were all wound in the same direction, and the terminal end of each was soldered to the beginning of the one succeeding it, so that the whole system of 16 spools virtually formed a single coil of wire surrounding the ring in a regular manner, and returning upon itself.

Wires were soldered to the separate points of juncture and were led, parallel to the axis of rotation, to an equal number of insulated pieces of brass, mounted in two rows upon, and slightly projecting from, the surface of a disc firmly secured to the axis.

The iron ring, with the bobbins wound upon it in the manner already described, was mounted in a horizontal position between the two legs of a powerful upright electro-magnet, the distance of which from the ring could be adjusted at pleasure by means of a set screw and a slot in the lower connecting cross-piece. Contact rollers, *k k*, were made to press, one on each side of the axis, against the lower wooden disc carrying the strips of brass, so that during the rotation of the ring all of the latter were brought successively into contact with them. When, therefore, the terminal posts, *h h'*, are placed in connection with the poles of a galvanic battery,

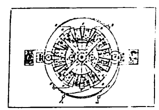

Fig. 24.

the current will pass, supposing it to enter at *h* (+), by way of the binding post, *l*, to the roller, *k*, and through the strip of brass on the disc against which the roller may happen to press at the time, up to the two wire coils of the armature whose point of juncture is in connection with this strip of brass.

The current here divides, each portion passing in an opposite direction through the spools surrounding each half circumference of the ring, to meet again to form one current at the left contact roller, b, from where the reunited current passes to the second binding post, f. From here the current proceeds to the leg A of the electro-magnet, circulates around it, and, after acting similarly with regard to the other leg, B, passes back by way of the binding post b' to the negative pole of the battery. Magnetic poles thus became developed in the iron ring at the points N S, the position of the contact rollers having been so chosen as to bring about this effect, and the actions of attraction and repulsion taking place between them and the poles of the stationary electro-magnet gave rise to the rotation of the ring.

In order to turn the action of the electro-magnet upon the magnetized iron ring to the greatest possible account, Pacinotti provided the two poles with armatures, AAA, BBB, of soft iron, which were made to surround the ring very closely for over two-thirds of its circumference. Strips of brass, FF, FF, attached, served to give them greater security. In the elevation of the machine here given these armatures have been omitted in order not to conceal the ring and its surrounding spools.

The foregoing description of the ring of Pacinotti and its action has more especial reference to its application in an electro-magnetic machine, but toward the end of his article Pacinotti clearly indicates in what way, by the use of the same annular armature, the electro-magnetic may be converted into a magneto-electric machine, capable of producing, by the proper use in connection with it of a permanent or electro-magnet, a continuous current of a constant direction.

On substituting for the electro-magnet AB a permanent magnet, and on rotating the ring armature, the poles induced in the ring by the proximity of the magnet will always be found at the extremities of the diameter passing, when produced, through the poles of this exterior magnet, so that we may come to consider the spools as alone partaking of the rotary motion, while the two semi-circular magnets produced by the induction remain at rest. The current induced in any particular spool will, in the motion of the latter from N to S, preserve the direction it has on leaving N until it reaches a, a point midway between N and S. Here a reversal in direction of the current takes place, which new direction is preserved until the spool arrives at b, a point midway between S and N, where a reversal to its former direction of the current occurs, and so the action continues. The currents developed in the different spools will therefore add to each other's effect, and are hence most properly collected at the points A and B, the collecting brushes coming thus to act upon the commutator at right angles to the magnetic axis of the rotating armature.

Pacinotti did actually obtain an uninterrupted current of constant direction on causing the opposite poles of permanent magnets to approach the ring during the rotation of the latter. He also obtained the same effect by magnetizing the stationary electro-magnet by means of a current, though he deemed the former method preferable.

The claim of Pacinotti to priority in the invention and application in magneto-electric machines of the annular armature has already been fully established, and is daily becoming more generally recognized.

SIEMENS-HALSKE MACHINE.

The following description is translated from the admirable treatise entitled "Die Magnet und Dynamo-elektrischen Maschinen," by Dr. H. Schellen, just published:

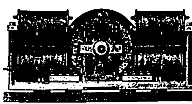

Fig. 35.

"We have already drawn attention to the fact that when metallic bodies are caused to move in a magnetic field, such motion develops in them induced, or so-called Foucault currents, which, if not conducted away, become transformed into heat, and thus, according to the circumstances of the case, give rise to a considerable heating of the metallic bodies in motion. As long, therefore, as the iron core revolves with the coiled drum through the magnetic field of the exterior magnets in the magneto-electric machine just described, these currents are not to be avoided, though they may be diminished to some extent by constructing the armature of coils of iron wire instead of massive iron. In such machines, however, which are built for the purpose of producing very large quantities of electricity, and which for this reason are constructed in accordance with the dynamo-electric principle, these Foucault currents would be attended by a considerable increase in the temperature of the machine, in addition to which considerable power would be required in order to rotate the iron armature, owing to its becoming so strongly polarized by the powerful electro-magnets developed, for which power there would be no equivalent return in useful effect.

"These considerations must have determined the inventor to secure the iron armature inside the drum, and so prevent it from taking part in the motion of the latter in such dynamo-electric machines, like those to be used for illuminating purposes, for instance, as are intended for the production of large quantities of electricity. As a matter of course, this renders the construction and mode of arrangement of the drum much more complicated, and all the more so when it is considered that the long drum, with its surrounding coils of wire, has to be moved through the narrowest possible space between the pole armatures of the electro-magnets and the stationary inner core.

"Figs. 35 and 36 represent the construction, in detail, of such a dynamo-electric machine on the v. Hefner Alteneck system. A horizontal section of the drum and a side view of the complete machine are there given. abcd is a thin German silver drum upon which, in the manner already de-

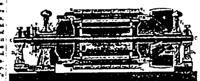

Fig. 36.

scribed, the wire is wound in many circumvolutions, and in eight separate coils. Each terminal face carries a short tube, which tubes form the trunnions of the drum, and which lie in boxes, F, and F_1, provided with oil cups. An iron shaft, CC, secured by means of screws in the pillars, D, and D_1, passes through these tubes into the interior of the drum, where the core, nn_1, ss_1, held together by two discs bolted to each other, is fastened upon it. The drum is surrounded on the outside at two opposite places for about two thirds of its circumference, and over its entire length, by two curved iron armatures, NN, and SS_1. These are placed as closely as possible to the wire drum, and form, with the stationary hollow interior core, nn_1, ss_1, a narrow annular space, the magnetic field, through which the drum abcd, with its surrounding wires, must be able to pass in its rotation with all possible freedom.

"Inside of the front hollow trunnion of the drum which rests in F, there passes another hollow tube, which is secured to the end face of the drum, and between which and the trunnion the ends ee, of the separate wire coils, are led through to the commutator, pp., attached to its front end.

"The two curved iron armatures, NN, and SS, terminate in flat plates, No Sm, and N_1o_1, S_1m_1, which constitute the cores of the electro-magnets, EE, E, E_1, and through which the armatures are rendered magnetic. These cores are united at their ends by strong soft iron connecting pieces, om and o,m, which also serve the other purpose of forming the side portions of the cast iron framework of the machine. Here also the wires of the two horse-shoe-shaped electro-magnets, E and E_1 are wound in such way that the poles of the same name are opposite each other, so that all portions of the iron arch uniting each set of these poles exhibit the same kind of polarity. In this way the drum and the interior iron core are surrounded for about two-thirds of their circumference, and over their entire length, by the stationary exterior magnetic poles, NN, and SS, and a very extended magnetic field formed by this means, the intensity of which will be the greater the more powerful the induced currents developed, and, in consequence, the poles of the electro-magnets, become.

"In order to carry out the dynamo-electric principle, the coils of the two electro-magnets, EE, and E_1E_1 are connected with the commutator brushes, or the contact rollers, in such a way that the current generated by the machine traverses successively the wire surrounding the drum, the coils of the electro-magnets, and the electric lamps placed in the circuit. The two sys-

American Gas Light Journal. Jan. 16, 1879.

[illegible] currents of the drum and the poles of the electro-magnets [illegible] to a certain maximum limit, a mutual strengthening action upon [illegible], which limit is determined by the stress upon the drum, the [illegible] saturation of the latter, and the mass of iron in the cores of the electro-magnets.

[illegible] drive so powerful a machine, a steam engine, or other such motive power will be required. As long as the current remains unclosed, and the [illegible] winding sources are not in metallic connection with each other, the [illegible] of the drum may be effected by the expenditure of sufficient force to overcome merely the friction in the journal boxes, F F. If, however, the external current is closed, by the introduction of an electric lamp, [illegible] the induced currents will at once be developed in the drum, [illegible] magnetism exist in the armatures, N N, and S S. These currents, [illegible] to the strength of the electro-magnets, exert a strengthening [illegible] the armatures, and thereby become themselves strengthened. The [illegible] electricity generated by the machine, as well as the mechanical power expended in running it, will thus rapidly become greater, since every increase [illegible] magnetism is attended by a corresponding increase in the strength [illegible] current. It is for this reason that, for certain purposes, [illegible] steady electric light, for instance, a uniform action of the driving [illegible] absolutely necessary, and all the motors designed to be used in [illegible] dynamo-electric machines must, on this account, be provided with [illegible] regulating contrivances, in order to secure such uniformity as [illegible] possible.

[illegible]ing the machine for the production of the electric light, it may [illegible] that, through any external cause, impurities in the carbons, for instance, the arc becomes extinguished and the current interrupted. In such [illegible] consumption of power on the part of the machine suddenly falls [illegible] zero, and a considerable (even dangerous) increase in the velocity [illegible] of the drum would be the consequence thereof, were the driving [illegible] to continue working at the same rate without having a corresponding [illegible]ance to encounter. In order to meet any such danger Siemens [illegible] Halske have provided their machine with an automatic switch, which

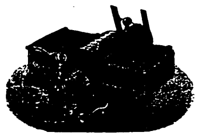

Fig. 27.

throws into the circuit an artificial resistance when, through any cause whatever, the circuit is interrupted in the lamps. * * *

"The machine represented in Figs. 25 and 26, has a length of about 10½ centimetres, a height of 32, and a width of 66½ centimetres, and yields, when the drum revolves at the rate of 450 per minute, for which six horse power are required, an electric light of 1400 standard candles. The current produced by it is capable of heating to redness a copper wire one metre long and one millimetre in thickness.

In the machines of medium and smallest size, in order to secure the necessary simplification in construction, the iron cylinder is firmly united with the wire coils, and rotates with them. The fixing of this inner armature, on the contrary, is rendered necessary in such cases in which there occurs a very frequent change of polarity, and in which the utmost utilization of the driving power is called for, which is usually only the case with the larger machines.

"Fig. 27 represents in perspective a Siemens-Halske machine (system of v. Hefner Alteneck), of the latest construction. The electro-magnets have the flat shape of those used in Wilde's machine. The current is taken off by means of metallic brushes, and the large number of radial pieces in the commutator shows that the drum carries a larger number of separate coils.

"In the latest machine of this form the commutator disc is done away with, and the ends of the separate wire coils surrounding the drum are connected with each other and led to the radial pieces of the drum in a somewhat similar manner to that obtaining in the Gramme machine which has already been described. These radial pieces are insulated from each other by means of asbestos paper. Contact rollers are no longer employed, their place being taken by flat elastic bands, formed of [illegible] silver plated copper wires.

"The smaller size of these machines is 5[illegible] mm. in length, [illegible] mm. wide, and 2[illegible] mm. high; the drum alone is 3[illegible] mm. long, and carries [illegible] wire coils and a commutator divided into 2[illegible] parts. Its weight amounts to 1[illegible] kilogrammes, the maximum velocity of the drum, [illegible] revolutions per minute, and the intensity of the light produced, 1,[illegible] standard candles. [illegible] and a half horse power are required to run it.

"The medium size differs in construction but slightly from the one just described. It is 7[illegible] mm. in length, [illegible] mm. wide, and 2[illegible] mm. high. The drum has a length of [illegible] mm., and is also wound with [illegible] wires. The commutator is, therefore, also composed of 2[illegible] pieces against which wire brushes are made to press. The machine weighs [illegible] kilogrammes, and produces, with its maximum velocity of [illegible] revolutions per minute, a light of [illegible] candles. It requires 3½ horse power."

(To be continued.)

(From the "Chemical News.")

The Nature of the Elements.

At a crowded meeting such as is seldom witnessed of the Royal Society, on Thursday evening, December 12th, 1878, Mr. J. Norman Lockyer, F.R.S., read a lengthy paper, in which he discussed the evidence derived from spectroscopic observations of the sun and stars and from laboratory experiments, which has led him to the conclusion that the so-called elements of the chemist are in reality compound bodies. In order that the line of argument followed by Mr. Lockyer may be understood, it will be necessary briefly to refer to the results of previous researches. As a rule, in observing spectra the substance to be examined is volatilized in a gas flame, or by means of sparks from an induction coil, and the light is allowed to fall on the slit of the spectroscope; the spectrum is then generally one in which the lines run across the entire field, but by interposing a lens between the spark apparatus and the slit of the spectroscope, Mr. Lockyer was enabled to study the various regions of the heated vapor, and thus to establish the fact, already noted by some previous observers, but to which little attention has been paid, that all the lines in the spectrum of the substance volatilized did not extend to equal distances from the poles. He then showed by the aid of this method that in the case of alloys containing different proportions of two metals, if the one constituent were present in very small quantity its spectrum was reduced to its simplest form, the line or lines longest in the spectrum of the pure substance alone appearing, but that on increasing the amount of the constituent its other lines gradually appeared in the order of their lengths in the spectrum of the pure substance. Similar observations were made with compound bodies. It was also noticed that the lines furnished by a particular substance varied, not only in length and number, but also in brightness and thickness according to the relative amount present. Armed with these facts and with the object of ultimately ascertaining more definitely than has hitherto been possible which of the elements are present in the sun, Mr. Lockyer about four years ago commenced the preparation of a map of a particular region of the spectra of the metallic elements for comparison with the map of the same region of the solar spectrum. For this purpose about 2000 photographs of spectra of all the various metallic elements have been taken, and, in addition, more than 100,000 eye observations have been made. As it is almost impossible to obtain pure substances, the photographs have been carefully compared in order to eliminate the lines due to impurities; the absence of a particular element as impurity being regarded as proved if its longest and strongest line was absent from the photograph of the element under examination. The result of all this labor, Mr. Lockyer states, is to show that the hypothesis that identical lines in different spectra are due to impurities is not sufficient, for he finds short line coincidences between the spectra of many metals in which the freedom from mutual impurity has been demonstrated by the absence of the longest lines. He then adds that five years ago he pointed out that there are many facts and many trains of thought suggested by solar and stellar physics which point to another hypothesis—namely, that the elements themselves, or, at all events, some of them, are compound bodies. Thus it would appear that the hotter a star the more simple is its spectrum; for the brightest, and therefore probably the hottest stars, such as Sirius, furnish spectra showing only very thick hydrogen lines and a few very thin metallic lines, characteristic of elements of low atomic weight; while the cooler stars, such as our sun, are shown by their spectra to contain a much larger number of metallic elements than stars such as Sirius, but no non-

LECTURE UPON THE ELECTRIC LIGHT.

Delivered Oct. 17, 1878, Before the American Gas Light Association,

By Prof. HENRY MORTON, Ph.D.,
Pres. Stevens Inst., Hoboken, N. J.

[Continued from page [illegible].]

In 1871 M. Z. T. Gramme, a cabinet maker, of Paris, presented to the French Academy the description of a new form of magneto-electric machine, possessing several new and remarkable features. Its general structure can be well understood from the accompanying figure, which represents one of its simplest forms as constructed with permanent magnets, and to be driven simply by hand power.

Fig. 28.

The large U magnets terminate in heavy end pieces, which constitute massive north and south poles, almost surrounding the armature, which constitutes the peculiar feature of this machine.

This armature consists of a ring made of a coil or hank of soft iron wire, around which are wound a series of coils of copper wire, in the the manner shown in Fig. 29, which represents such an armature partially dissected.

The ring made of a hank of iron wire is shown cut across and spread out to some extent, the cut ends appearing below B and at A. The several coils of wire are also represented partly in place above and spread apart in the lower part of the figure. The wire of these coils passes continuously from one to another, but between each makes a loop, which is hooked into a copper conductor, RR, constituting part of the commutator.

The general principle on which this machine acts can best be explained by reference to the diagram (Fig. 30). Let S and N represent the poles of the permanent magnet, and the divided ring between them stand for the ring of iron wire.

This ring, under the influence of the poles S and N, will always have a north pole at *n* and a south pole at *s*, the parts *p* and *p*, being neutral, or,

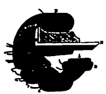

Fig. 29.

in other words, will correspond with two semi-annular magnets with their north poles together at *n* and their south poles together at *s*. The magnetic currents in the various parts of this ring will then be represented by the arrows drawn on it. As the ring rotates these poles will always maintain essentially the same position in space, and therefore, in relation to the coils wound on this ring, we might assume that this inner ring was at rest, and that the coils above were carried round over it.

Now let R indicate such a coil, and suppose it to move toward the right; it will evidently leave more magnetic currents in a given direction in the left hand semi-annulus than it approaches, and will therefore acquire a current in the direction shown by the arrow, to which will be added the effect due to approaching the opposite currents in the upper part of the

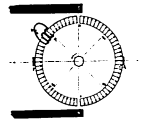

Fig. 30.

right hand semi-annulus. At *n*, and also at *s*, this action will reach a maximum, as the coil will be (at *n*, for example) approaching all currents of the right hand semi annulus and leaving all those of the left, and vice versa at *s*. At *p* and at *p*., however, the effect will be nil, as the coil would there approach and leave equal numbers of currents of like direction.

Now if we consider a number of coils all moving around from left to right, on the upper part of the ring the currents in them will have the same direction; and if they are all connected together these currents will aid each other, and may be taken off by conductors pressing on the commutators at *p* and *p*.. Let us suppose that the current is such as to make *p*. positive and *p* negative. As the coils pass *p*. the direction of the currents in them is reversed, but so also is their relation to the conductor or commutator. Thus, a coil which was coming toward *p*. from above was sending its positive current forward toward *p*.; as it leaves *p*., going onward below, its current being reversed, it no longer sends its positive current forward, but sends it back to *p*., which it has passed. Thus *p*. gets not only the positive current from the coils on the upper half of the ring, but from those also on the lower half.

By reason of the action which has thus been described, there is in the first place no rapid reversal of magnetism in the iron core of the armature, as in the Wilde machine, but only a continuous and progressive change as the ring rotates; and in the second place there is a continuous current of electricity in a constant direction, with only one reversal for each revolution of the entire set of coils.

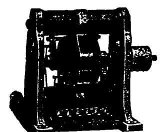

Fig. 31.

Of course the method of passing the current of one machine through the coils of an electro-magnet replacing the permanent magnets shown in Fig. 29, could be carried out with this machine just as with Wilde's; or the machine itself, being made with electro-magnets, these could be excited by its own current, as with the machines of Ladd and of Siemens, which we have already described. This last plan was, in fact, at once adopted, and the standard Gramme machine was made in the form shown in Fig. 31.

Here the electro-magnets consist of the large horizontal cylinders seen above and below, so wound with wire as to produce a combined north pole at the centre above, where the extension piece is attached, and a corresponding south pole below.

Within and between these extension pieces is the armature or bobbin, consisting of the iron ring wound with its numerous flat coils. The connections in this case are carried out on both sides of the axis, and thus several pairs of brushes can be applied, and numerous currents taken off.

With all these machines, however, the best effects are obtained by employing only one circuit, or passing the whole current from the bobbin

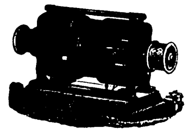

Fig. 32.

through the electro-magnet coils and the exterior circuit, where it is used.

In 1873 Wilde described a new form of magneto-electric machine, in which he abandoned the use of the Siemens armature, and returned, in general structure, very much to the form of the old Alliance machine.

Two sets of electro-magnets, 16 in each, were arranged in such a way that they formed two hollow cylinders opposite each other, with the poles of the magnets of each cylinder facing each other, but having space between for another cylinder of 16 electro-magnets, mounted parallel with the others, and carried by a disc of iron, from which they projected at each side. In fact, there were three cylinders of magnets, all having a common horizontal axis, the outer ones fixed and the inner ones rotating, so as to carry its magnets between the poles of the others.

Good effects were obtained with this machine, and the heating of the armatures was avoided, but it was not found to equal the improved Siemens or the Gramme in efficiency or economy of power.

In 1875 a patent was taken out in the United States by Mr. Moses G. Farmer for a machine essentially like that of Wilde, just described. This, with some modifications of details, is now manufactured by Wallace & Sons, of Ansonia, and has come into very general use.

In the experiments made by the present writer, as well as those conducted by the Franklin Institute, this machine seems to be inferior in "duty" to some others; but the conditions of such trials are so difficult to establish, in adapting the nature of the exterior circuit, including the lamp, to the

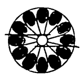

Fig. 33.

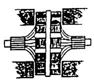

Fig. 34.

peculiarities of each machine, that I should not regard these conclusions as absolutely final.

In the Wallace-Farmer machine (Fig. 32) the magnetic field is produced by two horseshoe electro-magnets, but with poles of opposite character facing each other. Between the arms of the magnets, and passing through the uprights supporting them, is the shaft, carrying at its centre the rotating armature.

This consists of a disc of cast iron, near the periphery of which, and at right angles to either face, are iron cores, wound with insulated wire, thus constituting a double series of coils. These armature coils (Figs. 33 and 34) being connected end to end, the loops so formed are connected in the same manner, and to a commutator of the same construction as that of the Gramme. As the armature rotates, the cores pass between the opposed north and south poles of the field magnets, and the current generated depends on the change of polarity of the cores. It will be seen that this constitutes a double machine, each series of coils, with its commutator, being capable of use quite independently of the other; but in practice the electrical connections are so made that the currents generated in the two series of armature coils pass through the field magnet coils, and are joined in one external circuit. This form of armature also presents considerable uncovered surface of iron to the cooling effect of the air, but its external form, in its fan like action on the air, like that of the Brush, presents considerable resistance to rotation. In the Wallace-Farmer machine there was

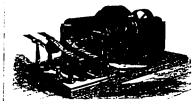

Fig. 35.

considerable heating of the armature, the temperature being sufficiently high to melt sealing wax.

Another machine made and used in this country to a considerable extent is that of Mr. Brush, manufactured by the Telegraph Supply Co., Cleveland, O. This is shown in *Fig.* 35.

The Brush machine has for its magnetic field two horseshoe electro-magnets, with their like poles facing each other, at a suitable distance apart, the circular armature rotating between them.

In this machine the currents are generated in coils of copper wire wound upon an iron ring, constituting the armature. This ring is not entirely covered by the coils, as in the Gramme armature, but the alternate uncovered spaces between the coils is almost completely filled by iron extensions from the ring, thus exposing large surfaces of the armature ring for the dissipation of heat, due to its constantly changing magnetism, as in the Pacinotti machine.

The ring revolves between the poles of two large field magnets, the two positive poles of which are at the same extremity of the diameter of the armature, and the two negative poles at the opposite extremity, each pair constituting practically extended poles of opposite character.

The coils on the armature ring are eight in number, opposite ones being connected end to end, and the terminals carried out to the commutator. Figs. 36 and 37 show this arrangement, only one pair of coils, however,

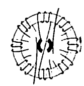

Fig. 36.

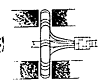

Fig. 37.

being shown in Fig. 36 as connected. In order to place the commutator in a convenient position, the terminal wires are carried through the centre of the shaft to a point outside the bearings.

The commutators are so arranged that at any instant three pairs of coils are interposed in the circuit of the machine, working, as it were, in multiple arc, the remaining pair being cut out at the neutral point; while in the Gramme machine, the numerous armature coils being connected end to end throughout, and connections being made to the metal strips composing the commutator, two sets of coils in multiple arc are at one time inter-

[illegible] the current, each set constituting one-half of the coils on the [illegible]

The commutator consists of segments of brass, secured to a ring of non-conducting material, carried on the shaft. These segments are divided [illegible] two thicknesses, the inner being permanently secured to the non-conducting material, and the outer ones, which take all the wear, are fastened [illegible] inner in such a manner that they can be easily removed when [illegible].

The commutator brushes, which are composed of strips of hard brass, [illegible] together at their outer ends, are inexpensive and easily renewed. [illegible] high speed at which these machines are run, together with the form of [illegible] armature, cause the rotation of the latter to be considerably resisted by [illegible] air, and producing a humming sound, but otherwise they run smoothly, [illegible] heating of the armature being inconsiderable, not exceeding 122° Fahr. [illegible] four and three-quarter hours run.

When the Jablochkoff candle came into vogue it became highly impor[illegible] to [illegible] one of the directions in which improvement had been [illegible] most of the recent machines, and produce a machine which should [illegible] alternating or reversing currents, in place of those passing continu[illegible] in one direction. This was necessary to equalize the consumption of [illegible] two parallel carbons of the Jablochkoff, and also even with other lamps, [illegible] purposes which we will explain further on.

To meet this requirement Gramme has arranged a machine which not [illegible] produces alternating currents, but operates readily, at the same time, [illegible] number of separate circuits. It is these machines which were recently

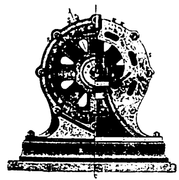

Fig. 38.

used during the Exposition to light certain streets and public places in Paris. The general appearance of this machine is shown in Fig. 38.

This machine, it will be observed, differs radically from the continuous current machine of Gramme.

In the first place, it is, as it were, turned inside out. Thus there is a magnetic ring wound with successive coils, but this, in place of revolving within the field of fixed electro-magnets, is stationary on the outside, while a series of eight electro-magnets, excited by a separate machine, rotate in the interior of this fixed armature ring.

The principle of the machine will be readily understood from the diagram (Fig. 39).

The interior system of electro-magnets is so wound that the polarity of each spoke is reverse to its neighbors. These magnets, therefore, by induction develop eight consecutive poles in the soft iron of the surrounding ring, and as they revolve the poles of this ring move with them. Thus, while in the older Gramme machine the actually moving ring had poles stationary in space, over which the coils passed, in this case the actually stationary ring has moving poles which pass through the stationary coils.

These coils are wound in eight sets, each alternate set being wound in an opposite direction, and each set is made up of several separate coils; to facilitate the making of all sorts of combinations, which are most easily arranged in this machine, as no commutators are used, and all the coils are fixed.

If all the coils marked a are connected together, it is evident that at any moment the currents in all of them will be in the same direction. Thus, suppose the electro-magnet spoke 2 to have a north pole at its outer end, and 3 to have a south pole similarly situated, then as 2 moves over a it will produce a current alike in direction to that produced by the opposite pole of 3 moving over the oppositely wound wire of the next coil marked a.

Of course, as the magnet 2 leaves a and the oppositely polarized magnet 1 approaches, this current will be reversed in the first coil marked a, and also likewise in the second coil a, for a like reason.

It has been stated that these machines worked one Jablochkoff candle for each horse power consumed, but several who watched their actual running say that very much more power was actually consumed.

THE LONTIN MACHINES.

Among the machines for generating electricity that have commanded more or less of general attention, may be included the magneto and dynamo-electric machines devised by Lontin. In their mode of construction and arrangement these machines possess features which recall the Alliance and Holmes magneto machines on the one hand, and the Siemens and Gramme dynamo machines on the other.

There are two styles of Lontin dynamo machines, the one yielding continuous currents of one direction, and the other producing alternating currents.

In the machine of the first form, a number of bar electro-magnets are disposed radially about a central shaft of soft iron, and the star shaped wheel thus formed is made to revolve between the poles of an ordinary powerful U shaped electro-magnet. The wire of the electro-magnet wheel

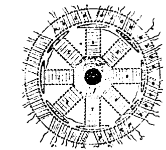

Fig. 39.

forms one complete circuit, and is connected at the several point of juncture of each two successive magnet coils, with the appropriate section of a commutator, placed upon the axis of the machine. On revolving the wheel between the poles of the stationary upright field magnet it will readily be seen that, considering any individual radial electro-magnet, there will be induced in the coil of the latter, during its motion away from one pole and its consequent approach to the opposite pole, a current which, though varying (first diminishing and then increasing) in intensity, will still maintain a constant direction until the coil has arrived at the opposite pole, where a reversal of the current will take place. The current will continue flowing in this new direction until the revolution of the wheel brings the coil back to the pole from which we have considered it to start, when and where the current will be restored to its former direction. At any moment, therefore, during the revolution of the wheel, all the electro-magnet coils in the upper half of the wheel will be traversed by a current flowing in one direction, and all those in the lower half by one in the opposite direction. Elastic strips, one on each side, bear against the commutator in the line where the reversal takes place, and lead away the currents to the proper binding posts. The mode of generation and direction of the currents in this form of the Lontin machine is thus seen to be exactly similar to that obtaining in the Gramme machine.

The stationary electro-magnets are included in the main circuit, in accordance with the dynamo-electric principle. By mounting several of these wheels of electro-magnets, with separate commutators and field magnets, on the same central shaft, an equal number of independent currents may be obtained, which by appropriate means may of course be combined in any desired manner.

By winding the alternate electro-magnets on each wheel in opposite directions, the machine may be made to produce currents constantly varying in direction. The Lontin machine proper, for alternating currents, has, however, a more elaborate form, bearing a rather close resemblance to the machine devised by Holmes.

The Lontin machine consists essentially of an electro-magnet wheel, like that in the first described form of the machine, only that the magnets are much more numerous, amounting in number to 24 and over, and are wound in the manner just referred to—that is, the alternate magnets are wound in opposite directions; and of a large stationary soft iron ring surrounding the wheel concentrically, to which ring there are secured, at equal distances apart, a number of short electro-magnets, equal in point of number to the electro-magnets on the inner wheel. The electro-magnet coils of the revolving wheel are connected together, so as to form one circuit. The current necessary for the saturation of these magnets is obtained from an auxiliary machine (a Lontin machine of the first form, for instance), mounted upon the same axis, connections being so made, by means of brushes and collars, that the rotation of the large wheel does not interfere with the circulation of the current. The ends of the electro-magnets, during the rotation, pass very closely by the cores of the outer stationary magnets, and as the successive magnets on the wheel present opposite poles to these cores, constantly alternating currents are induced in these outer magnets. One series of terminals of the coils of these magnets is led to one binding post, while the other passes to a set of circuit-closing devices, by means of which all of the currents, separately or together, or any individual one or more, may be conducted away from the machine.

The great merit of this second form of the Lontin machine lies in the facility with which currents varying in number and intensity may be derived from it, so that quite a number of electric lights may be produced at the same time, and also in the fact that in the conducting away of these currents contact brushes are entirely dispensed with; so that the great loss in electricity attendant upon this mode of collection, besides the frequent attention required by its use, are entirely avoided.

With a velocity of rotation of 320 turns per minute, the machine being arranged so as to yield 12 separate currents, the outer magnets being connected together two and two for this purpose, 12 lights were obtained, each equivalent to 750 candles. Three series of 8 magnets each gave 3 lights, each having an intensity of 1,690 standard candles.

It is said that to prevent any detriment to the machine arising from the conversion into heat of any currents that may not be required, while the remaining ones are being applied to some special purpose, these superfluous currents are made to pass through appropriate resistance coils, and thus become in a manner absorbed.

A large Lontin machine of the kind last described was used at one time for lighting the railway depot at Lyons, where it fed 31 separate lamps, each giving out a light of about 340 candles. The power needed to run this machine is not stated. Another machine of this form, giving 24 lights of 1,690 candles, required from 20 to 22 horse power to drive it. Smaller machines, of from 2,000 to 3,000 candles, demand somewhat more than 3-horse power.

SIEMENS' NEW MACHINE.

Siemens and Halske have lately devised a new dynamo-electric machine, for the production of one or several independent currents, which may be made at pleasure either intermittently unidirectional or rapidly alternating in character.

In one form of this machine the two sides of an upright iron frame carry each a series of 8 circularly disposed electro-magnets, the cores of which stand out at right angles to the sides, and carry at their ends, where they face the corresponding cores of the opposite series, large flat plates of soft iron. The plates of each set are alternately of opposite polarity, while those facing each other exhibit the same polarity; and as the space between them is made as small as the mode of construction will permit, magnetic fields of high intensity and of alternately opposite polarity will come to be formed.

Upon a shaft running through the centre of the frame there is secured a disc, carrying on its circumference an upright iron ring, oblong in section, made either of wire or plates, sometimes also of massive iron. This ring is surrounded at eight (or more, in some forms of the machine) equidistant places by flat coils of insulated copper wire, which, with the ring, are carried by the rotation of the shaft through the magnetic fields formed by the electro-magnets. Two of the coils on the rotating ring are devoted exclusively to the purpose of keeping the field magnets saturated, in accordance with the well-known dynamo-electric principle; and since the current in these coils must be constant in direction, a special commutator is provided to secure this result. The alternating currents obtained from the remaining coils are conducted away from the machine by means of collars and brushes in the ordinary manner.

The great resemblance of this machine to a machine of the Brush form, in which eight sets of electro magnets are employed, instead of the usual two, need scarcely be pointed out.

Several forms of the machine above described are manufactured by Siemens and Halske, the details varying with the purposes to which it is intended to apply any particular machine. The larger machines possess one important distinctive feature, in that no iron is made use of in the construction of the revolving disc, the cores of the coils being formed of wood, or some other non-magnetic material. By this mode of arrangement the hurtful inductive effects, the production of Foucault currents, the loss of power by conversion into heat, and the like, attendant upon the use of iron in this connection, come to be entirely avoided.

(To be continued.)

GAS LIGHTING v. ELECTRIC LIGHTING.

By Thomas Nesham Kirkham, M.I.C.E., & F.C.S., and Thomas Hersey,
LATE OF THE IMPERIAL GAS LIGHT COMPANY, LONDON.

The gas scare continues, and is likely to do so, while day after day the newspapers insert fresh pieces of news as to the progress of electric lighting, each new thing, if only true and practicable, sufficient to considerably injure the gas companies.

As, however, there is not at present much real data as to the cost and value of the electric light from experiments in England open to the public we, as experienced gas engineers, have investigated for ourselves the data furnished by M. Hippolyte Fontaine as to the results of using the electric light in France, and we have personally examined the Jablochkoff system as shown at Messrs. Wells & Co. in Shoreditch, that of Mr. Werdermann in the Euston Road, the Rapieff system at the "Times" office, and the Lontin light at the "Gaiety" Theatre.

But, before going into the cost and value of the electric light, we, as having a considerable knowledge of the management of the Metropolitan Gas Companies desire to say that we are utterly at a loss to understand the reason for the cry raised against them by the newspapers, which, almost without exception, appear to have a grievance, and to represent that the public in general have great cause for complaint; and as we know this to be without adequate foundation, we think it right to say so, and to point out that it is almost impossible for any producers of an article for sale to be more stringently kept from going wrong—even if they desired to do so—than are the Metropolitan Gas Companies, and especially those of them that are under the more recent legislation, which represent share and share and loan capital amounting to £9,570,571 out of a total in the Metropolis of £11,843,749.

The new legislation binds the companies under it to give an illuminating power of 16 candles, and that they do give this, and more, is proved by the official testing of the Metropolitan Board of Works and the Corporation of London, who would be ready enough to enforce the penalties if there had been default, as has been proved by the enforcement on two or three occasions of the severe penalties for slight excesses in the sulphur impurity which the companies are compelled to keep as low as the Referees appointed by the Board of Trade can reasonably call upon them to do.

As regards pressure, the Act of Parliament has prescribed a minimum, but it is very seldom that it is even approached, so desirous are the companies that a full supply of gas should be afforded to all their customers; but with the enormous business of the companies there must necessarily arise defects from time to time, and all they can do is to have a sufficient staff of inspectors and workmen ready to remedy them without unnecessary delay. It should, however, be understood that much the larger number of complaints arise from the defects in fittings or burners belonging to the consumers for which the companies are not in any way responsible.

As regards the meters, the companies supply them at a rental to almost all their customers, although they are not compelled to do so except as to the smaller sizes of meters; but the consumers of gas can, if they please, purchase meters for themselves from any maker, and, so long as they are good enough to obtain the official stamp for correctness of registration, the companies must allow them to be used. "Correctness," however, means that meters may be stamped as correct if they register three per cent. against the companies, but they are not allowed to pass if they register more than two per cent. against the consumer. So even in this the consumer is favored at the expense of the companies.

We are quite at a loss to understand what the sins of the companies are, 4081½

LECTURE UPON THE ELECTRIC LIGHT.

Delivered Oct. 17, 1878, before the American Gas Light Association,

By Prof. HENRY MORTON, Ph.D.

Pres. Stevens Inst., Hoboken, N. J.

(Concluded from page 34.)

In addition to the other forms or modifications of magneto-electric machines—by which name I intend to designate all that I have already described, as I do not think that the term dynamo-electric machines, to designate those in which electro-magnets, excited by the machine itself, are used as producers of the "field of force" or magnetic field in which the revolving magnets move, as distinguished from the earlier sort, using permanent magnets or the like, is at all necessary—there are some others which should not be passed over without notice.

In the first place, Mr. Edward Weston, of Newark, is manufacturing a machine resembling exactly in appearance, and, as far as I can see, in all essentials of construction, that which I have already described and shown as Siemens' later form. (See Fig. 27.) With several of these machines I have made numerous trials lately, and find them to run well for as much as ten hours at a time, and to give a higher efficiency in light per horse power than any of the other machines with which I have experimented. This result seems to agree with the general result of experiments made in Europe with the machines of Siemens, and with a general verbal statement which

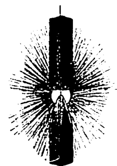

Fig. 40.

was made to me as to the result of experiments at the U. S. Torpedo Station at Newport, R. I., where they have one of these Siemens machines.

There is also a very efficient machine manufactured by Messrs. Arnoux & Hochhausen, of New York. Some of these were used very successfully last summer for lighting the bathing beach at Coney Island, and for lighting several points in New York during the holiday season this winter, and the new State House at Albany during its inauguration.

One of these was kindly loaned to me on the evening of the address here reported, but as it was soon afterward required for use by its manufacturers I have not had an opportunity to make any examination of, or experiments with it. It much resembles the second form of Wilde, or the Farmer machine in general arrangement.

In describing the various forms and modifications of these machines I have not attempted in all cases to follow the chronological order of each step, as this would sometimes have involved the skipping about from one type of machine to another. I will now, therefore, give an abstract of the chronology of the subject, following Dr. Schellen's book as an authority for a part of the list:

1831. Faraday discovered magneto-electric induction.
1832. Pixii made first magneto-electric machine.
1833. Saxton made magneto-electric machine.
1836. Clarke made magneto-electric machine.
1849. Nollet-Van Malderen—Alliance machine.
1853. Holmes introduced electro-magnets.
1857. Siemens introduced peculiar armature.
1864. Pacinotti, the first continuous current machine.
1866. Wilde made his first form of machine.
1866. Siemens & Halske, same principle as Ladd.
1867. Ladd, self-exciting principle.
1867. Wheatstone developed same principle.
1871. Gramme first described his continuous current machine.
1872. Wilde describes his second form.
1873. Siemens describes his machine. (Fig. 27.)
1873. Farmer patented machine like Wilde's second.
1874. Lontin machine, for many circuits.
1878. Gramme's alternating machine.

In considering the practical application of the electric arc as a source of light, it becomes very important to notice with accuracy just what is the chief location of light in the ignited poles, and how this may be affected by various conditions.

Thus, in the first place, if we are using a machine with a current of uniform direction, we will find that the upper or positive pole, as they are generally arranged, soon acquires a cup-shaped form, as shown in Fig. 40, and that the most intensely luminous portion of the carbon is the interior of this positive cup. The edges of this cup will evidently cut off this light from spreading upward for a very considerable angle, while on the other hand all the light from this interior luminous area will pass freely downward. From this it will of course follow that very different results would be obtained if, with such machine and arrangement of the carbons, the lights were measured from below, or on a level, or from above

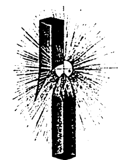

Fig. 41.

If the two carbon points are not placed truly in line with each other, then we have such a state of affairs as is shown in Fig. 41.

Here, evidently, while the light from the hollow positive pole would radiate freely in front, it would be largely cut off behind, and escape only with a medium degree of facility at either side; in fact, measurements made with such arrangement show the following figures:

Representing by 100 the light emitted, in a horizontal position, when the points are in line, we have for the various directions, when they are displaced as shown in Fig. 41:—In front, 287; laterally, 116; backward, 38.

In the report of experiments made by a committee of the Franklin Institute (see Journal of that Society, vol. 75, p. 301) I find the record of a similar set of measurements, as follows:

Front........................	2,218	candles.
Side........................	578	"
"	578	"
Back	111	"
	3,485÷4=871	

"The light produced by the machine, under the same conditions, except the carbons being adjusted in one vertical line, was 525 candles. This would seem to indicate that nearly 66 per cent. more light was produced by this adjustment of the carbons; but a close study of the conditions estaisfied us that such is not the case, and that there is no advantage to be derived from such adjustment, except when the light is intended to be used in one direction only."

This shows us, among other things, how very great a difference of result in candle power may be obtained with the same apparatus, if a difference occurs in the arrangement of the points; and it also explains why an arc which gives a very high candle power when measured, may quite fail to exhibit anything like an equal degree of actual illuminating power when put to some practical use.

Thus, in the case just cited, while the candle power, measured from the front, would be 297, the average for all directions would be only 139, or about one-half as great.

In this connection a certain advantage is found in the use of machines with alternating currents. Here the carbons both burn away alike to pointed ends, and the light is thus much more equally distributed on all sides. (See Fig. 42.)

In most of the machines now in use the current which produces the light is the same which passes around the coils of the stationary magnets, by which the field of force is developed; hence there is the most intimate relation between the machine and the lamp, and any fluctuation in the resistance offered at the latter is at once felt at the machine. To eliminate this source of uncertainty and irregularity, in some experiments which I have lately conducted with various machines I have employed a simple, substantial holder for the carbons, with means of adjustment from time to time by hand. This requires, of course, the frequent attention of an assistant during the experiments, but by this means I have obtained more constant and favorable results, from all the machines tried, than with any of the automatic lamps.

Next to this I have found the Brush lamp to be most satisfactory, when used with its own machine.

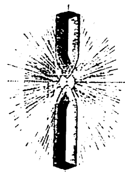

Fig. 42.

As the structure of this lamp is very simple, I will give a description of it here.

This lamp is shown in Figs. 43 and 44, in which *a* is a helix of insulated copper wire, resting upon an insulated plate, *b*, upheld by the metallic post, *c*. Loosely fitted within the helix is the core *d*, partly supported by the adjustable springs *e*. The rod, *f*, passes freely through the centre of the core, *d*, and has as its lower end a clamp for holding the carbon pencil. A washer, *h*, of brass, surrounds the rod, *f*, just below the core, *d*, and has one edge resting on the lifting finger attached to the latter, while the other edge is overhung by the head of an adjustable screw stop, *s*.

The metal post, *c*, is supported and guided by a tubular post, *i*, secured to a suitable base plate. Attached to the lower end of the post, *c*, and passing out through a slot in *i*, is the arm, *g*, supporting an insulated holder for the lower carbon.

If now one conducting wire from the machine be connected to the base plate, and the other to the lower carbon holder, the current of electricity will pass up through the posts, *i* and *c*, through the helix *a*, rod, *f*, and the carbons, *kk*, thus completing the circuit.

The axial magnetism produced in the helix will draw up the core, *d*, and it, by means of the lifting finger, will raise one edge of the washer *h*, which, by its angular impingement against the rod, *f*, clamps and lifts it to a distance controlled by the adjustable stop, *s*, but separating the carbon points far enough to produce the light.

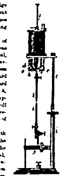

Fig. 43.

As the carbons burn away, the increased length of the electric arc increases its resistance, and weakens the magnetism of the helix, and therefore the coil, rod, and carbon move downward by the force of gravity until, by the shortening of the arc, the magnetism of the helix is strengthened, and the downward movement arrested. When, however, the downward movement is sufficient to bring the clutch-washer, *h*, to the support, *g*, it will be released from the clamping effect of the lifting finger, and the rod, *f*, will slip through until arrested by the upward movement of the core, due to the increased magnetism of the helix.

The normal position of the clamp-washer is with the edge under the adjustable stop, just touching the support, *g*, the office of the core being to regulate the slipping of the rod through it. If, however, the rod, from any cause, falls too far, it will instantly and automatically be raised again, as at first, and the carbon points thus sustained at the proper distance from each other.

In the lamps used in these experiments, the helix was composed of two separate insulated wires wound together, so that, by means of suitable pin contacts, shown at the top of Fig. 10, they could be connected either in

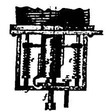

Fig. 44.

couples or end to end, thus varying the intensity of the magnetism of the helix. Thus, in connection with varying the weight to be lifted by the magnetism of the helix, either by loading the core or increasing the upward thrust of the springs, enabled us to adjust the lamp to suit the varying qualities of the currents dealt with.

Several new methods of arranging the carbons, and rendering them more or less adjustable automatically, have been recently suggested or put in practice.

Thus, in *Nature* for Dec. 19th, 1878, I find a plan described by Wilde, which consists in placing two carbon rods beside each other, as in the Jablochkoff candle, but without any insulating material between them. Under these circumstances the author states that the arc will keep to the extremities of the rods, or will run to them if established elsewhere.

To provide against extinction, and secure automatic relighting, one of the holders is hinged so as to allow its carbon to fall against the other unless pulled away by an electro-magnet in circuit. This arrangement is certainly very simple, and free from many of the objections offered in connection with the Jablochkoff candle. It will be seen here, however, that the maximum light will be developed between the two rods, or, in other words, on their respective inner surfaces where it will have the least facility for producing useful effect.

A very curious modification of this candle has been made by Mr. Edward Weston, in which he places a strip of some relatively volatile matter on the backs or outer sides of the parallel carbon rods. The arc then forms across from these parts, and the incandescent vapor assumes much the appearance of a gas flame.

Among the recent forms of lamp described in Dr. Schellen's recent work, "Die Magnet- und Dynamo-Elektrischen Maschinen," are several announced by the Siemens-Halske firm.

In one of them, two carbons inclined towards each other, are allowed

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... downward, and thus bring their upper ends together by the withdrawal downwards of a non-conducting interposed rod, whose motion is controlled by an electro-magnet in the circuit.

In another, which, however, looks like a suggestion rather than a practicable machine, the carbons are arranged so that the lower one is constantly vibrating up and down, and the upper one simply rests upon it, except in so far as it is being constantly knocked away by the motion of the lower one, which motion is effected by an electro-magnet in the circuit.

A much more complete apparatus, on the same general principle, we will describe presently.

Among the latest developments in electric lamps may be reckoned the plan of Mr. Werdermann, which may be described as follows:

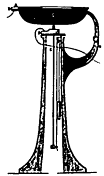

Fig. 43.

Mr. Werdermann makes one electrode to consist of a disc of carbon, tapering in thickness from the centre to the circumference on one side, and flat on the other. The other electrode is a very fine and thin rod of carbon, with one end pointed. The disc is placed horizontally with the rounded side downwards, and the thin rod vertically, and in contact with the disc, the current being supplied via the metal collar by which the rod is surrounded near the top. On passing the electricity the fine point of the carbon rod above the collar becomes incandescent, and a very small electric arc is produced between the two carbons. Referring to the diagram (Fig. 43), the upper carbon is shown at c, and the rod carbon at r. The former is supported by means of an adjustable jointed bracket B, attached to the wood stand. The rod carbon is guided by the spring collar on the top of the stand, and to which the connection is made, and is supported by the fine cord, running over the pulley P. This cord is attached to the clasp D at the bottom of the rod and to the balance weight W, by which the rod is maintained in constant, practical, though not absolute contact with the disc. Round the upper part of the disc is a metal band A, to which the circuit wire is attached, and the current thus passed on to the next lamps.

"This lamp, (says the *Ironmonger* of Nov. 9), "was tried on October 28, and again on November 6, on the works of the British Telegraph Manufactory (Limited), Euston Road, London, the current being derived from a small Gramme machine of two-horse power. At the commencement two lights were maintained equal to 640 candles, and the light was perfectly steady. Subsequently the current was sent through a row of 20 lamps, the light of each being equal to 40 candles; still the light was steady. Mr. Werdermann asserted his ability to distribute the current from the small machine then at work so as to divide it among 60 lights. In that case the light would inevitably be small; but enough is apparent to prove that, so far as a current will bear division, Mr. Werdermann will be able to utilize it."

It will be noticed that here, as with all other lamps working by incandescence, there is great loss, which increases with the subdivision. A Gramme machine utilizing two-horse power should give, with an ordinary lamp, a light of from 1,000 to 1,500 candles, in place of the 640 here claimed from two lamps, or the 400 candles claimed for ten lamps.

A yet more recent system is that developed, or, we might rather say, now in course of development, by Profs. Elihu Thomson and Edward Houston, of Philadelphia, which they have themselves described as follows:

"As is well known, when an electrical current, which flows through a conductor of considerable length, is suddenly broken, a bright flash, called the extra spark, appears at the point of separation. The extra spark will appear, although the current is not sufficient to sustain an arc of any appreciable length at the point of separation.

"In our system, one or both of the electrodes, which may be the ordinary carbon electrodes, are caused to vibrate to and from each other. The electrodes are placed at such a distance apart that in their motion toward each other they touch, and afterward recede a distance apart, which can be regulated. These motions or vibrations are made to follow one another at such a rate that the effect of the light produced is continuous; for, as is well known, when flashes of light follow one another at a rate greater than 25 to 30 per second, the effect produced is that of a continuous light. The vibratory motions may be communicated to the electrodes by any suitable device, such, for example, as mechanism operated by a coiled spring, a weight, compressed air, etc.; but it is evident that the current itself furnishes the most direct method of obtaining such motion, as by the use of an automatic vibrator, or an electric engine.

"In practice, instead of vibrating both electrodes, we have found it necessary to give motion to but one, and since the negative electrode may be made of such size as to waste very slowly, motion is imparted to it, in preference to the positive. The carbon electrodes may be replaced by those of various substances of sufficient conducting power. In this system, when desired, an independent battery circuit is employed to control the extinction and lighting of each lamp.

"The following is a description of one of the forms of electric lamp which we have devised, to be used in connection with our system of electric lighting:

"A flexible bar, b, of metal is firmly attached at one of its ends to a pillar, p, and bears at its other end an iron armature, a, placed opposite the

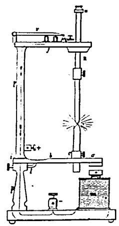

Fig. 44.

adjustable pole-piece of the electro-magnet, m. A metal collar, c, supports the negative electrode, the positive electrode being supported by an arm, j, attached to the pillar, p. The pillar, p, is divided by insulation at i into two sections, the upper one of which conveys the current from the binding post, marked +, to the arm, j, and the rod, r, supporting the positive electrode.

"The magnet, m, is placed as shown by the dotted lines, in the circuit which produces the light. The pillar, p, is hollow, and has an insulated conducting wire inclosed, which connects the circuit closer, v, to the binding post, marked —. The current is conveyed to the negative elec-

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circle through b and the coils of the magnet, m. When the electrodes are in contact, the current circulating through m renders it magnetic and attracts the armature, a, thus separating the electrodes, when, on the weakening of the current, the elasticity of the rod, b, again restores the contact. During the movement of the negative electrode, since it is caused to occur many times per second, the positive electrode, though partially free to fall, cannot follow the rapid motions of the negative electrode, and therefore does not rest in permanent contact with it. The slow fall of the positive electrode may be insured either by properly proportioning its weight, or by partly counterpoising it. The positive electrode thus becomes self feeding.

"The rapidity of movement of the negative carbon may be controlled by means of the rigid bar, l, which acts, practically, to shorten and lengthen the part vibrating. In order to obtain an excellent but free contact of the arm, j, with the positive electrode, the rod, e, made of iron or other suitable metal, passes through a cavity filled with mercury, placed in electrical contact with the arm, j. Since the mercury does not wet the metal rod, e, or the sides of the opening through which it passes, free movement of the rod is allowed without any escape of the mercury. We believe that this feature would be introduced advantageously into other forms of electric lamps.

"In order to prevent a break from occurring in the circuit when the electrodes are consumed, a button, v, is attached to the upper extremity of the rod, E, at such a distance that when the carbons are consumed as much as is deemed desirable, it comes into contact with a tripping lever, t, which then allows two conducting plugs, attached to the bar, v, to fall into their respective mercury cups, attached, respectively, to the positive and negative binding posts by a direct wire. This action practically cuts the lamp out of the circuit."

"PHILADELPHIA, Sept. 13, 1878."

In a later publication (Journal of the Franklin Institute for January, 1879), the same inventors describe a further modification and extension of their system, as follows:

"The following apparatus was devised by the authors for the purpose of obtaining induced reversed currents for use in electric illumination. These currents we use with a vibrating lamp, a description of which has already been published.

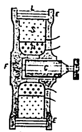

Fig. 47.

"Our method of operation is as follows:—A reversed primary current is caused to induce reversed secondary currents in secondary coils provided therefor. These secondary currents are caused to give vibrations to to certain electrodes, and thereby at the same time produce a partial arc between them. With sufficient strength of primary current, a considerable number of secondary currents are obtained, each of which is able to operate one of our vibrating lamps.

"The use of a vibrating lamp admits of a wide range in the size of the carbons employed. When a light of very moderate intensity is desired, the carbons are made of very small size, and are placed in a closed glass vessel for protection from the atmosphere. To moderate the brilliancy opalescent glass is used. To obtain the highest efficiency of inductive action from a set of primary coils, the following form of induction coil was devised:—the primary coil, P, surrounding the core, C, is provided with a secondary coil, S, adjacent to it. The ends E and F of the bobbin are made of disks of iron concentric with the core, C, and slit from centre to circumference. The outer extremities of these disks are connected by wires or sheets of iron, L, to one another, forming in this manner an induction coil encased in iron, or one whose core has its north and south extremities magnetically connected. The strength of the current developed in the secondary coil is greatest when the core, C, which is movable, is inserted so that both of its extremities are in contact with E and F. By withdrawing this core, the currents in the secondary coil may be weakened to almost any desired extent. This coil is best adapted to the use of primary currents whose direction is constantly changing. All the wire being completely surrounded by iron, whose direction of magnetic polarization is rapidly changed, the highest inductive effect is thereby produced in the secondary coil.

"The variations in the intensity of the induced currents will, of course, be followed by variations in the intensity of the light emitted by the lamp. The movement of the core may therefore be made to increase or decrease the intensity of the light."

With this notice of the newest, or, as we may say, youngest system of electric lighting, which has its birthday with the new year, I may well conclude this hastily prepared and imperfect notice of this very interesting subject, and if what I have here thrown together may supply at least material for a fuller treatment, or a skeleton on which a completely organized structure may be constructed, I shall have accomplished all that I could hope.

Before concluding this address I should draw attention, in a more direct manner, to something which has been developed indirectly in the course of my remarks, and that is that the loss of efficiency in the electric force as a means of producing light, when it is divided, is not a unique phenomenon, but is exactly paralleled in the case of ordinary combustion.

If gas is burned in very small flames we may get almost no light from it, and, on the other hand, if we burn it in very large flames, the amount of light developed will increase in a much higher ratio than will the amount of gas consumed.

Thus I have here a new burner made by Sugg, of London, with three concentric argand rings which burns 30 feet of gas, and yields a light equal to 196.4 candles. The same amount of the same gas burned in six standard five foot burners yielded a light of 114 candles. Here is a gain of over 70 per cent. in the total light produced, by simply concentrating the combustion in one large flame in place of dividing it into six small ones.

In the case of the ordinary lime-light we have another instance of yet further concentration.

Here, with a consumption of about 7½ feet of gas an hour, in a burner with three jets heating a cylinder of lime from all sides, we obtain a light equal to 300 candles in every direction.

This shows very clearly the illogical character of the comparisons so often made between the concentrated light of the electric arc and the divided light of the ordinary gas burner.

Heretofore electric lights have only been practically developed in their concentrated form, and it certainly has not yet been shown that, when divided there will be an enormous loss of efficiency. Gas, on the contrary, has heretofore only been practically used in its divided form, and there can be no doubt that its efficiency is capable of much increase when it is burned in a concentrated manner.

It is here where the actual contest will come in, and the relative success of the two sources of light in each field will depend upon what it will accomplish in that field and not in some other. In other words, we must compare the divided electric lights (say Mr. Edison's, when they become visible) with ordinary burners, and the electric-arc light with the lime-light, or some such concentrated form of gas burning.

THE END.

[From Translation in "Van Nostrand's Magazine."]

The Gas Engines at the Paris Exhibition.

By M. Armengaud, Jr.

ABSTRACT OF THE AUTHOR'S ADDRESS AT THE CONFERENCE DU TROCADERO.

The attention of most of those in attendance at this Conference has been drawn at the Exposition to certain machines, which, in their general appearance and mode of working, resemble steam engines. But upon approaching them it is readily seen that the similarity is only apparent; the movements of these motors are accompanied by a series of slight detonations, and a near inspection reveals the fact that attached to each is a perforated chamber, within which burns a flame which seems to give life to the machine. These are the gas motors. The motive power is derived from illuminating gas, not from steam.

It is proposed to present to the conference some explanations of the structure and mode of working of the different engines of this class exhibited at the Champ de Mars, and to consider the possible future achievements of these engines if they continue the progress so clearly made manifest by this exposition.

Such a progress would hardly seem to possess sufficient interest to hold the attention of an audience not composed exclusively of engineers. But it is proposed to relieve the subject of its technical character as far as possible, and present the more general form of discussion. The task is rendered easy by the very happy circumstance that in the working of a gas engine we find a summary of the most beautiful applications of scientific principles.

A gas motor possesses the essential organs of the steam engine; the cylinder which receives the gaseous fluid; the piston which, by aid of a rod and crank, transmits the pressure to the shaft; the fly-wheel which regulates the motion; and the pulleys and belts by which the power is conveyed to the machines to be driven.

The gaseous fluid is a mixture of gas and air, in such proportions as is

Complainant's Exhibit "Preece Philosophical Magazine Publication of January, 1879," Feb'y 28, 1890. S. M. H., Exr.

EXTRACT.

From the "Philosophical Magazine"—Vol. VII. Fifth Series, pp. 29 to 34. London, January, 1879.

III. THE ELECTRIC LIGHT.

By W. H. Preece, Memb. Inst. C. E., V. P. Soc. T. E., Electrician General Post-office, &c. *

1. The theory of the electric light cannot be brought absolutely within the domain of quantitative mathematics, for the reason that we do not yet know the exact relation that exists between the production of heat and the emission of light with a given current; but we know sufficient to predict that what is true for the production of heat is equally true for the production of light beyond certain limits.

The work done in a battery, or any source of current-electricity, is expended outside the battery in a closed circuit in the form of heat. When this heat acquires a certain temperature per unit mass, we have light. If the heat be confined to a mass of metal wire like platinum, we have light by *incandescence*; if it be expended in the transference of minute particles of incandescent matter like carbon across an air space, we have the *electric arc*. The exact relations between the current, heat, temperature, mass, and light have yet to be determined by experiment.

2. The arc is thus formed of energy developed in one point of a circuit, which is the exact equivalent of another form of energy expended in another point of the circuit. Thus, if we produce light by a galvanic battery, it is the equivalent of chemical work done in the battery. If it be produced by a dynamo machine

* Communicated by the Author.

driven by a steam engine, it is the equivalent of coal consumed in the furnace. The object to be attained in any economical utilization of this energy is to convert the greatest possible portion of it into light.

3. Now the relations that exist between the work done, the current flowing, the resistances present, and the heat developed are easily demonstrated. The work done (W) in any circuit varies directly with the electromotive force (E) in that circuit, and with the quantity of electricity (Q) that passes through it, or

$$W=EQ\,;$$

but by Ohm's law the electromotive force is equal to the product of the resistance (R) of the circuit into the current (C) flowing, or

$$E=CR\,;$$

and by Faraday's law the quantity of electricity passing depends upon the strength of current (C) and the time it flows (t), or

$$Q=Ct.$$

Therefore, substituting these two values in the above equation, we get

$$W=C^2Rt\,;$$

in which we have what is known as Joule's law, which gives us the work done (W), or its equivalent, the heat generated (H) in any circuit. By regarding the time as constant, we can put the equation

$$H=C^2R \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

4. Now let us take the case of a battery whose electromotive force is E and whose internal resistance is p. Let the resistance of the connecting wires be r. Let us also have a particular resistance l, which may be a wire to be heated to incandescence, or a lamp to be lit by the arc; then by Joule's law (1),

$$H=C^2(p+r+l);$$

but by Ohm's law,

$$C=\frac{E}{p+r+l}$$

$$\therefore\ H=\frac{E^2}{p+r+l}$$

5. Confining our attention for the present to the heat generated (H), this will be distributed throughout the circuit; and that in the resistance (l) will be

$$H\times\frac{l}{p+r+l}=\frac{E^2l}{(p+r+l)^2} \quad . \quad . \quad . \quad . \quad (2)$$

Now if we suppose n resistances in circuit joined up in *series*, then the total heat generated will be

$$H'=\frac{E^2nl}{(p+r+nl)^2} \quad . \quad . \quad . \quad . \quad (3)$$

If we differentiate this fraction with respect to nl and put it equal to nothing, we can find when the heat generated in these resistances becomes a maximum; that is,

$$\frac{dH'}{d\,n\,l}=\frac{1}{(p+r+nl)^4}\,[(p+r+nl)^2E^2-2E^2nl(p+r+nl)]=0,$$

whence

$$p+r+nl=2nl\,;$$

that is,

$$p+r=nl\,;$$

or *the greatest heat is generated in the resistances when the value of the latter equals the resistances of the rest of the circuit.*

6. Let us now assume the n resistances to be connected up in *multiple arc;* then the joint resistance will become $\frac{l}{n}$ and the heat generated will be

$$H''=\frac{E^2\frac{l}{n}}{(p+r+\frac{l}{n})^2}\,; \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and the maximum amount of heat will occur, as before, when

$$p+r=\frac{1}{n}.$$

7. Now, in the first case, if the internal resistance of the battery and of the connecting wires be very small compared with nl, we may neglect them; so that by putting p+r=0, equation (3) becomes

$$H'=\frac{E^2}{nl};$$

or *the total amount of heat generated in the resistances will vary inversely as the number of the latter in circuit.*

8. In the second case, we cannot neglect p+r: for here the greater we make n, the smaller $\frac{1}{n}$ becomes with respect to p+r; so that if eventually $\frac{1}{n}$ becomes very small, we may neglect it in the denominator of the fraction. Then

$$H'=\frac{E^2\frac{l}{n}}{(p+r)^2}=\frac{E^2l}{n(p+r)^2}; \quad . \quad . \quad . \quad . \quad (5)$$

so that in this case also *the total heat generated in the resistances will vary inversely as the number of the latter in circuit.*

9. Now it must be observed that in each of these cases the total heat is distributed over n resistances; and therefore, as compared with one resistance, the heat generated in each is only $\frac{1}{n^2}$ of that generated in one. So that, *joined up either in series or in multiple arc, the heat generated in each of a number of resistances varies inversely as the square of their number.*

10. With respect to the light emitted, if the amount of heat generated represented exactly the amount of light emitted, then the above equations would indicate

the effects produced by multiplying the lights or subdividing the current when a constant battery is employed. But this is not so. The light obtained is not proportional to the heat generated. Below a certain limit the production of heat is not accompanied by light at all. In the case of incandescence, if the heat be distributed over two wires instead of one, inasmuch as the mass to be heated in the one case is double that in the other, the actual temperature to which each of the wires will be heated will be only one-quarter of that obtained with one wire, and the *total* light emitted will be half what it was before. In the case of the arc a similar result probably takes place: the incandescent matter, which is heated by the current and which gives out the light, is increased by the addition of each lamp, and therefore diminishes the actual temperature of each arc, and consequently diminishes the light given out in direct proportion to the number of lights.

11. Moreover, in the arc the actual disintegration of the carbons and the transference of matter across the air-space, represent an amount of work done which must be deducted from that converted into heat, and which again tends to diminish the amount of light emitted. If, therefore, the lamps be joined up in series or in multiple arc, the light emitted by each lamp will vary inversely in a greater ratio *than* the square of the number in circuit.

12. We have assumed E to be constant; but, if the current be produced by a magneto or dynamo-machine worked by a steam-engine consuming a given amount of coal per unit time, E is no longer constant, for it varies with the resistances in the circuit. The constant in this case, is the work done in the steam-engine in unit time. Calling this W_1, the total heat generated in the circuit when the lamps are joined up in series will be

$$H_1 = W_1 \times \frac{nl}{p+r+nl}; \quad . \quad . \quad . \quad . \quad (6)$$

and since the light varies inversely as n (§ 10), the light emitted

$$L_1 = W \times \frac{nl}{n(p + r + nl)}; \quad . \quad . \quad . \quad . \quad (7)$$

and when joined up in multiple arc.

$$L_2 = W_1 \times \frac{\frac{l}{n}}{n\left(p + r + \frac{l}{n}\right)}; \quad . \quad . \quad . \quad . \quad (8)$$

Or by putting $p + r = 0$ in equation (7), and $\frac{l}{n} = 0$ in the denominator of equation (8), we get

$$L_1 = \frac{W_1}{n}$$

and

$$L_2 = \frac{W_1 l}{(p+r)n^2}$$

So that *beyond* certain limits, when the current is produced by a dynamo-machine, if *n* lamps be joined up in series, the total light becomes diminished by $\frac{1}{n}$ and the light emitted by each lamp becomes diminished by $\frac{1}{n^2}$.

If they are joined up in multiple arc, the total light is diminished by $\frac{1}{n^2}$, and the light emitted by each lamp $\frac{1}{n^3}$

In the latter case the rapid diminution in the light emitted is due to the fact that the heat is developed in the machine itself instead of in the resistances external to it.

13. We have assumed W_1 to be constant; but this is only the case when a certain limit is reached, and when the velocity of the rotating coils in the dynamo-machine has attained a maximum. This limit will vary with each

dynamo-machine and each kind of lamp used. With the Wallace-Farmer machine the limit appears to be reached when six lamps are connected up in series. With the Gramme alternating machine and Jablochkoff candles the limit appears to be five lamps. Beyond these limits the above laws will be true. It is this partial success in multiplying the light that has led so many sanguine experimenters to anticipate the ultimate possibility of its extensive subdivision—a possibility which this demonstation shows to be hopeless, and which experiment has proved to be fallacious.*

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* *Vide* Fontaine's "Electric Lighting," Chapter XI.

Complainant's Exhibit "Preece Telegraphic Journal Publication of February 15, 1879." February 28, 1890. S. M. H., Exr.

The Telegraphic Journal, Vol. VII.
February 15th, 1879, pp. 59-60.

THE CRITERIA OF THE ELECTRIC LIGHT.

We extract the following passages from a very instructive lecture to the Royal United Service Institution, by Mr. W. H. Preece:

Heat and light are identical in character, though different in degree; and whenever solid matter has imparted to it motion of a very high intensity—in other words, when solid matter is raised to a very high temperature—it becomes luminous. The amount of light is dependent upon the height of this temperature; and it is a very remarkable fact that all solid bodies becomes self-luminous at the same temperature. This was determined by Daniell to be 980°, by Wedgewood 947°, by Draper 977°; so that we may approximately assume the temperature at which bodies begin to show a dull light to be 1,000°. The intensity of light, however, increases in a greater ratio than the temperature. For instance, platinum at 2,600° emits forty times more light than at 1,900°. Bodies when raised to incandescence pass through all stages of the spectrum; as the temperature increases, so does the refrangibility of the rays of light. Thus, when a body is at a temperature of—

Temperature °	
250	it may be called warm.
500	" " hot.
1,000	we have the red rays.
1,200	" " orange rays.
1,300	" " yellow rays.
1,500	" " blue rays.
1,700	" " indigo rays.
2,000	" " violet rays.

So that any body raised to a temperature above 2,000° will give us all the rays of the sun. Inversely, the spectroscope may thus be enabled to tell us the temperature of the different lights, and it is, perhaps, because some lights do not exceed 1,300° that we lose all those rays beyond the yellow. * * *

Dr. Tyndall has shown that the visible rays of an incandescent wire bear to the invisible rays a much smaller proportion than in the arc, and it is generally assumed that for the same current the arc will give at least 2½ times greater light than an incandescent wire; in fact Dr. Tyndall's figures are as follows:

	Visible rays.		Invisible rays.
Gas.............	1	to	24
Incandescent wire	1	"	23
The arc..........	1	"	9

* * * * * *

The requirements of a good electric lamp are, first, intense brilliancy; secondly, great steadiness; thirdly, duration. The Serrin lamp has the first kind of excellence; all those lamps based on incandescence excel in the second respect; The Wallace-Farmer light is the only one that attains the third point. The Rapieff is, perhaps, the form which up to the present most nearly combines the three requisites, but in reality no lamp has yet been introduced which fulfills all three requirements.

The objections to the use of the electric light are:

1. The deep shadows it throws.

2. The indifferent carbon that has hitherto been manufactured for the purpose, which leads to unpleasant sounds, to great variation in the intensity of the light and to waste.

3. The difficulty in distributing the light itself. It is so intense and confined to so small a space that it does not lend itself to distribution like the gas flame which occupies a considerable space.

4. The unsteadiness of the light due to variations in speed of the engine employed in driving the dynamo machine. There is another cause of variation in the

electric arc, and that is, the variation in the resistance of the arc itself, for it has been clearly demonstrated by experiments both in America and in England, that the resistance of the arc varies as the resistances in circuit vary. The following table will show this:

Current in Webers.	Light Candles.	Resistance of Arc ohms.
10	440	2.77
16.5	705	1.25
21.5	900	1.67
30.12	1,230	.54

The light in the arc varies directly as the current, and not as the square of the current as is generally assumed.

Now, in the case of light raised by incandescence, the light will increase as the square of the current. It follows that if in the one case, viz., the arc, the light increases as the current only, and in the other case, viz., incandescence, it increases as the square of the current, a point is reached when the light produced by incandescence will equal that produced by the arc. The difficulty in reaching that point is the difficulty in obtaining a conductor with a sufficiently high point of fusion to resist the effect of powerful currents. Iridium is the only metal that is known to do this, and iridium is too scarce and too dear to be used for the purpose.

The multiplication of the light by Gramme's machine upon the Thames Embankment must not be taken as the solution of the problem of the subdivision of the light. Theory shows unmistakably that to produce the greatest effect we must have only one machine to produce only one light. We know from absolute measurements that such a machine can be used to produce a light of 14,880 candles, and it is possible to produce 1,254 candles per horse-power. But the moment that we attempt to multiply the number of lights in the circuit this power diminishes, so that we have on the Embankment lamps giving us a light of scarcely more than 100 candles. The light of

the Rapieff lamp in the "Times" office appears to be about 600 candle power, and the Wallace light is equal to 800 candle power. In these two instances, six lights are used in one circuit, but we have not here the subdivision of the light, we have, on the contrary, the multiplication of the light, produced by the increased speed of the engine, due to the insertion of additional lamps. It is, however, easily shown, that in a circuit where the electro-motive force is constant, and we insert additional lamps, then when these lamps are joined up in one circuit, *i. e.*, in series, the light varies inversely as the square of the number of lamps in circuit, and when joined up, as in multiple arc the light diminishes as the cube of the number inserted. Hence, the subdivision of the light is an absolute *ignis fatuus*. In the first place, no machine has yet been produced which is competent or capable of lighting over 20 lamps; secondly, no conductor is known but copper, competent to convey the current required to light these lamps, and copper is an expensive material. Thirdly, no electric light has yet been produced which combines all the criteria needed for a good light.

Complainant's Exhibit "Engineer and Engineering Extracts." Feby. 28, 1890. S. M. H., Exr.

"ENGINEERING," February 21st, 1879, p. 161.

(Editorial.)

"EDISON'S ELECTRIC LIGHT APPARATUS.

* * * * * *

"Whether Mr. Edison's system of utilizing electric currents for the production of light can compare favorably with other systems can only be satisfactorily demonstrated by actual experiment and experience. It will be severely handicapped against all electric arc systems by the physical drawback common to all incandescent systems, namely, that for each addition to the number of lights in circuit an enormous reduction is made in the intensity of the light produced. We, therefore, cannot but believe that we have not yet seen the system by which Mr. Edison states, in his most recent letters to this country, that he is able to place 678 electric lamps in one circuit."

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"THE ENGINEER," January 10, 1879, p. 30.

(Editorial.)

"THE ELECTRIC LIGHT.

* * * * *

"Electricians who were not commercially interested "in any form of electric lamp or machine showed that "this subdivision could only be effected at an enormous expense for light and material, owing to causes "which we need not stop to explain. Again very thick "conductors are essential to any success in subdividing the electric light, and we shall be under the mark "if we state that the cost of copper wire alone for conductors in London, assuming the power to be concentrated in a very few stations, and the light to be extensively subdivided, would amount to some £15,-"000,000 or £20,000,000. If thin conductors are used "the loss of light is enormous, and this truth Mr. "Edison has apparently only just discovered, for he "admits that under his system it will be impossible to "obtain more than one-tenth of the light which could "be had with a given power and moderate subdivision. "* * * Before the electric light can be subdivided "with facility and economy, the operation of some new "law must be discovered, and this we hold to be extremely improbable."

* * * * * *

"THE ENGINEER," February 14, 1879, p. 114.

(Editorial.)

"THE EDISON LECTRIC LIGHT.

* * * * * *

"With all its defects for domestic purposes, still Mr. "Edison's lamp might perhaps be used to much advantage for street lighting, and in factories, or "threatres, in fact, in any situation where it could be "looked after by a skilled attendant. If the current "can be successfully divided among dozens of such "lamps, then may gas-makers quake, but nothing of "the kind can be done."

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Complainant's Exhibit "Higg's Book of 1879." Feby. 28, 1890. S. M. H., Exr.

THE ELECTRIC LIGHT IN ITS PRACTICAL APPLICATION.

By Paget Higgs, L. L. D., D. Sc.

London, 1879. P. 214

CHAPTER X.

Division of the Electric Light.

"The Division of the Electric Light" is a term the true rendering of which should be the "Division of the Electric Current" to produce numerous small light centres instead of one or more powerful lights. Much nonsense has been talked in relation to this subject. Some inventors have claimed the power to "indefinitely divide" the electric current, not knowing or forgetting that such a statement is incompatible with the well-proven law of conservation of energy.

Whether the electric current be utilized in the production of light, either by means of the voltaic arc or of incandescence, the production of a certain amount of light depends upon the amount of current passing, not directly, but in such a proportion that offers speedy limit to the number of lights to be obtained. The law is a very simple one. It is that the heating effect of the electric current will be proportional to the square of the amount of current multiplied by the resistance, both expressed in convenient units. Suppose, then, that two lights exist of a certain power each on two circuits derived from a main circuit, and that two more lights are required to be added, one in each on other two circuits again derived from the main circuit; the current formerly passing in each of the circuits when only two existed will be halved by the introduction of the other lights, and, according to the law, the heating effect in each circuit will be only one-fourth of that occurring with two lights. Actually, as the lighting effect bears to the heating effect much the same rela-

tion as the heating effect does to the amount of current, the decrease of light is much greater. With a given current-source, the division of the electric current is, therefore, anything but "indefinite."

Even with gas, which possesses the great advantage of yielding a large number of small lights, the greatest economy is obtainable with concentrated lights; and it is well known that the ignition of extra burners on a pipe of small diameter materially reduces the light in those burners already ignited. Though noticeable in a much less degree, because obeying a different law, with a fixed supply of gas the reduction of light arising from the ignition of fresh burners is appreciable and shows that the electricians who claimed "indefinite" subdivision exceed what is required or possible.

The subject of providing numerous small lights from one electric source is not new, and has always had great attraction for electricians. M. Chanzy's system appears to have been the first, but of this there is no record in detail.

Lacassagne and Thiers were the next (1854) to devote their attention to this subject, and the following is a description of their method as recorded in the specification of the letters patent: "When in any part of the circuit the current has to pass through a liquid of less conductivity than that of the reophores, the intensity or quantity of electricity passing in a given time is inversely proportional to the resistance of the interposed liquid. This resistance may be increased or diminished, either by an increase or decrease of the conducting power of the liquid or of the surface immersed. The magnetic force of an electro-magnet varies with the intensity of the current. If the surfaces of the conductors immersed in the liquid are of an unchangeable metal, we obtain in a free state the gas arising from the decomposition of the liquid; the quantity of this gas in a given time being in direct proportion to the intensity of the current."

Lacassagne and Thiers arranged two conductors of a battery to each of the poles, attached a plate of platinum to each extremity and suspended the plates in the interior of a glass gasometer containing acidulated water. The bell of the gasometer was raised or lowered by the inlet or outlet of the gas produced by the current. The ascent of the bell produced, of course, a diminution of the galvanic intensity, whilst its descent produced the opposite effect. An electro-magnet with an armature adjusted in the form of a lever, and an opposing spring, completed the arrangement. The spring was first adjusted to the strength of the current determined upon. As long as the magnetic attraction was greater than the tension of the spring the armature remained in contact, and as the gas which was developed had no outlet, the bell of the gasometer was raised, thus diminishing the surface of the platinum in contact with the liquid and consequently the quantity of the current.

De la Rive and Wartmann observed, in 1867, that, with sensitive electric lamps, the current could be interrupted for the thirtieth part of a second without interruption of the light, but that the interruption for one-tenth of a second sufficed to cause extinction. Le Roux took advantage of this discovery, and by means of a distributing wheel revolving at high speed sent the current alternately into two lamps, thus maintaining perfect equal lights.

Mersanne, in 1873, extended Le Roux's idea, replacing the distributing wheel by a horizontal spindle carrying a series of cams. The cams imparted reciprocating motion to a series of rollers attached to vertical metallic arms which made contact with mercury caps. Several lamps were thus successively introduced into the circuit, and the lights could individually be any power required, regulated by the length of interruption.

The same end has recently been attained by Mr. Cowling Welch, who distributes the current by a rotating switch successively over a number of circuits.

The nearest approaches to practical subdivision of the electric light have been made by Brush, Jablochkoff and Edison, with the systems we have described, and without doubt the most economical method will be that in which the largest number of lamps or burners are included in a single circuit. The reason for this is almost

obvious; for whereas, the reduction in lighting power in multiple arc is greater than in relation to the square of the number of lights, in the case of a series of lamps on a single circuit, the reduction results from the loss of current due only to the increased resistance, a matter merely of direct proportion.

Complainant's Exhibit "Du Moncel La Lumiere Electrique Article No. 1." Feb'y 28, 1890. S. M. H. Exr.

LA LUMIERE ELECTRIQUE.

VOL. I., NO. 1, PP. 2-3.

[Published prior to May 15, 1879.]

(Translation.)

CONSIDERATIONS ON PUBLIC LIGHTING BY ELECTRIC PROCESSES.

The peculiar charecter of electric light is a power of concentration so great, that in a single light one can obtain a brightness surpassing that of two thousand Carcel burners. This property, which may be extremely useful and important in certain applications, notably for the illumination of lighthouses and ships, is evidently a disadvantage from the point of view of public lighting, and the means have long been sought for dividing this brightness between several luminous centres, not only to weaken it to the sight, but also in order to illuminate a larger extent. Unfortunately, the processes of division tried hitherto have solved this problem only at the price of a great loss in the intensity of the light which could be produced at a single point. But we shall see that by a well-coutrived arrangement, we can nevertheless succeed in utilizing it under sufficiently good conditions.

It is certain that if the luminous centers which are established give a light that is much too intense to be directly supported by the eye, one is obliged to weaken it by diffusing globes which results in the pure waste of a large amount of it. This is the case with the Jablochkoff candles, the enameled glass globes of which absorb as much as 43 per cent. of the light developed; but if, by any means whatever, we should succeed in dividing it enough so as not to have need of these diffusing globes, this diminution would disappear and it might come to pass, with a suitable arrangement, that, notwithstanding a considerable loss of light in comparison with that which would be produced by a single centre, one would still find advantage in employing this system; first, because this illumination does not, like the others, entail a considerable heating of the medium which surrounds the centres, and in the second place, because, with this system, the risks of explosion and of fire would be no longer to be feared, and because the decorations of the apartments would not be damaged.

Besides, the white light which is produced does not cause the colors of the objects illuminated to be altered to the eye; finally, by reason of running less risks the insurance companies will evidently be able to diminish their rates.

From the point of view of expense itself, it might come to pass that electric lighting could be less expensive than lighting by gas, although the experiments made hitherto seem to indicate the contrary; but it must be considered that these experiments are not yet complete, and we already see, since the Jablochkoff system has been set up in the Avenue de l'Opèra, that the cost price of each electric burner, which, it was said, was in the beginning five times as great as that of gas, has been reduced by half in the estimates presented to the City of Paris by the company, and we even believe that it could be still further reduced, so as to entail an expense of only 40 centimes per burner and per hour. It might, it is true, be objected that the price of gas for an equivalent light is but 27 centimes; but suppose that the globes, which absorb 45 per cent. of the light produced, extinguish only 24 per cent. of it, as Monsieur Clémendot thinks himself able to assure, the expense would fall below that of gas. These data, of course, are only very approximate, and I cite the preceding figures only to show that it will not be impossible to produce the electric light at a price permissible in practice. In any case, the company which works the Jablochkoff candles has rendered an immense service in showing that the lighting of the public roads by electric light was possible, which had before that been doubted, and it may be said that, thanks to its initiative and to the fine experiments that it has been able to undertake, electric lighting has become an important question, and that, in all countries, new researches have been brought forward which will sooner or later lead to the solution of the problem. Already several cities in Europe and America are to be lit up by this system.

It is from now on certain that a completer study of the division of the light cannot fail to lead to more satisfactory results than those which are known to-day.

In order that an idea may be formed of the improvements which may be expected, I need but to say that in the studies that have hitherto been made, sufficient attention has not been given to the divers elements which play a most important part in the greatness of the effects produced. Thus a well-ordered proportion between the resistance of the exterior circuit and that of the generator can increase the work obtained in a large proportion; on the other hand, the fact must not be lost sight of, that the intensity of the light varies in an infinitely greater proportion than the intensity of the electric current. It is already known that the heating effect of this current varies as the square of this intensity. But the light which results therefrom again varies in a much higher ratio. For, according to Mr. Preece, a platinum wire heated to 2,600° gives a light forty times stronger than when heated to 1,900°. This explains why the division of the light is effected with great loss, for, from each diminution of the current arising from this division, there results a loss of light which might, under certain conditions, reach the 11th power of the ratio in which the current has become weakened.

In order to give an idea of the importance of a good balance between the resistances of the interior and exterior circuits, we have but to cite the results of the experiments made at South-Foreland.

Between the light-house and the machine-shops,

694 feet apart, there had been laid, for the use of the electric light, three cables, two of which, composed each of seven wires of copper No. 14 (B. W. G.) and connected together to constitute the circuit, formed a total length of 1,286 feet with a resistance of 0.32 Siemens' units, or almost 33 metres of telegraphic wire.

With Holmes' machine, which offered the greatest resistance, the loss in luminous intensity was estimated at 16 per cent.; with the Gramme machine, of much less resistance, it was estimated at 31.3 per cent., and with the Siemens machine, the least resistant of all, it was able to reach 43.4 per cent. By employing a cable of less resistance, this loss, with the Siemens machine, was reduced to 23 and 24 per cent.; but it became 35 per cent. when, by uniting two Siemens machines, in quantity, their total resistance was diminished by half. The application of this cable of less resistance to an Alliance machine produced a loss of 69.1 per cent. of the total light, and, with Holmes' machine, this loss amounted to 65.1 per cent. Finally, with two Holmes machines united, the loss rose to 76.5 per cent. These experiments therefore show that, in order to obtain the conditions for a maximum luminous yield, it is necessary that the resistance of the conducting wires should be in proportion to that of the machine.

All these considerations show that the solution of the problem of electric lighting still necessitates much research in order to become wholly practical; but we believe that no one of the questions which depend upon it is insolvable and that before long we shall be able to witness at least a partial transformation of public lighting.

Quite recent experiments made with Werdermann lamps and an Alliance machine have given more satisfactory results than those which we have previously mentioned on the subject of the Reynier lamps. The reason of this is, no doubt, that in the latter only the incandescence of the movable carbon has been utilized, while in the others the apparatus were regulated in such a way as to furnish, beside the incandescence, the voltaic arc due to the repulsion of the contiguous elements of the same current. In fact, as I have been assured, they have been able to obtain the lighting of twelve lamps, each giving a light of five gas-burners, with the current of an Alliance machine with four disks. If the cost price of the electric power with this machine is estimated at 1 fr. 10 per hour, as Monsieur Reynaud has calculated it in his experiments for the lighting of light-houses, each lamp with the Werdermann system, would come to 0 fr. 09 per hour, or 0 fr. 018 per gas-burner, that is to say, a price less than that of the gas in the ratio of 0 fr. 018 to 0 fr. 025 cent.

It is certain that with the systems of this kind, enameled globes, which absorb so much light, may be dispensed with, to a certain extent, for the brightness of five gas-burners may be easily endured whereas the brightness of twenty-five or thirty burners becomes impossible to stand. In this manner, the great force of light, which is so prejudicial to the Jablochkoff candles, can thus be avoided. Under the present conditions, electric lighting might thus perhaps be employed with a certain advantage; and this advantage might gain in importance if it is considered that, applied to the illumination of a small room, it would avoid the great production of heat which the gas would furnish in the same situation. It would not, on the other hand, be liable to produce explosions and fires which unfortunately are too often to be deplored; and again it would not have the disadvantage of damaging, like gas, the gilding and the decorations of the apartments in which it would be employed.

Finally, its white color would not alter the color of the exposed objects to the sight.

The insurance companies, besides, have so well appreciated the importance of this system of lighting in regard to danger of fire, that, according to what has been told me, they would be ready to reduce their rates in cases where it would be applied.

We therefore believe that, if the solution of the problem of electric lighting is not yet complete, there has been made, in recent times, a real progress, which, being wisely studied, might lead to wholly satisfactory results.

TH. DU MONCEL.

Complainant's Exhibit "La Lumiere Electrique Article No. 5." February 28. 1890. S. M. H., Exr.

[*La Lumiere Electrique*, Vol. I., No. 1, pp. 8 and 12. (Published prior to May 15, 1879.)]

TRANSLATION.

EDISON'S PROGRESS.[1]

We have finally been able to obtain information on the French patent of Mr. Edison and, far from removing the impression produced by the reading of the *Scientific American*, more than ever, are we convinced that the system of electric lighting of the learned philosopher of Menlo Park is very much beneath his reputation, and that nothing, absolutely nothing, in the new patent, should be the cause of the panic which it has raised among the gas managers in Europe as well as in America. It is truly an immense and lamentable hoax.

We are forced to say that, from a theoretical point of view, the apparatuses contrived by Mr. Edison are far from being absurd; the patent contains some ingenious details and some very original contrivances; but from a practical standpoint, the only thing of interest to holders of gas stock is commonplace, childish or impossible to realize. We should not even speak of this patent if its titutlary had not the extraordinary ability to invent the phonograph. It is, above all, the errors of great inventors which it is necessary to combat, because they are the most dangerous.

The Edison patent contains nearly fifty figures; we will publish only those which contain even the germs of the invention and we will lay one side the numerous mixtures (*variantes*), which really are of no interest.

Like every complete system of electric lighting,

[1] *Revue industrielle.*

this one contains an electric generator and a regulating lamp.

[Note.—Here follows a description with cuts of the electric generator and some forms of the platinum lamp described in Mr. Edison's French patent dated February 4, 1879, No. 127,341.]

Upon the whole, all these combinations are neither good nor new, and we do not hesitate, in spite of the remarkable discoveries that Mr. Edison has made in other scientific branches, to condemn absolutely his vibrating (dynamo) machine and his thermo-regulating lamps. However, we believe that the experiments which are being carried on in the laboratory at Menlo Park will be heard from (*n'ont pas dit leur denier mot*) and that they will give birth to some more practical ideas.

It would be unjust to condemn from first to last all the labors of Mr. Edison upon electric lighting, because the first attempts have been based upon some recollections impracticable in the actual case.

There are really to be found withal in the new patent the equivalent of the electro-magnetic diapason of Helmholtz; the regulator of Moncel of currents by an expansion rod passing through the interior of the incandescent spiral; the platinum spiral of M. DeChangy; the reciprocating armature of M. Froment; the rheostat of Wheatstone, etc.

Decidedly, the holders of gas stock can sleep tranquilly, the invention which is going to destroy the value of their shares is not yet conceived.

(*Revue industrielle.*)

Complainant's Exhibit "Parliamentary Evidence, April-June, 1879." February 28, 1890. S. M. H., Exr.

REPORT

FROM THE

SELECT COMMITTEE

ON

LIGHTING BY ELECTRICITY,

Together with the

PROCEEDINGS OF THE COMMITTEE,

MINUTES OF EVIDENCE,

AND APPENDIX.

Ordered by THE HOUSE OF COMMONS, *to be Printed,*

13 *June*, 1879.

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MINUTES OF EVIDENCE.

Friday, 25th April, 1879.

MEMBERS PRESENT.

Mr. Adam.	Lord Lindsay.
Mr. Alfred Gathorne-Hardy.	Mr. Arthur Moore.
Mr. Hardcastle.	Earl Percy.
Mr. Mitchell Henry.	Dr. Lyon Playfair.
Sir Ughtred Kay-Shuttleworth.	Mr. Puleston.
	Mr. Rylands.
	Mr. Spencer Stanhope.
	Mr. Christopher Talbot.

The Right Honorable LYON PLAYFAIR in the chair.

Professor JOHN TYNDALL, D. C. L., LL. D., F. R. S., called in and examined:

1. CHAIRMAN: We all know who you are, so that I need only ask you, for form's sake, what position you hold in the Royal institution? I am Professor of Natural Philosophy in the Royal Institution.

2. And you are successor to Faraday? I am Faraday's successor.

3. In that capacity you have, no doubt, paid much attention to electricity? I have paid considerable attention to electricity.

* * * * * * *

78. Have you, from a scientific point of view, paid attention to the experiments reported to us as having been made in America by Mr. Edison? I have paid a good deal of attention to that subject. Mr. Edison is an uncommonly clever man, and although one sees very serious difficulties in his way, one would be hardly entitled to say that he will not overcome those difficulties; but I do not know that he has up to the present time overcome them.

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93. Could not that be improved by using platinum, or iridium, or some other substance than carbon? I am afraid, as regard public illumination, incandescence, will not do; the expenditure would be too great. The intense light is produced by the partial separation of the carbon points. The current, as the chairman remarked at the beginning requires a certain resistance in order to produce light. In the case of the electric light, this resistance is a space of air over which the current has to leap, and it is in gathering up the force necessary to leap across that interval that it is enabled to give us that intense light. In a continuous circuit it would involve the expenditure of an enormous amount of electricity to attain the same amount of luminosity.

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105. You showed us the ignition of plantinum wire by the passage of the electric current; have not experiments been made to use the ignition of such a wire and inferior conductors, or of alloys with iridium, and so on with a view of using that as the source of the electric light instead of the carbon points? I do not know that that has been proposed with regard to public illumination, but I remember with the greatest distinctness,

more than 30 years ago, seeing a lamp formed upon that principle and exhibited in Manchester. The incandescence of plantinum wire by the electric current was known before Davy made his experiments in 1810. Children raised plantinum to incandescence by his battery; and at the time to which I refer, I saw a very pretty lamp on a table in Manchester ignited by the voltaic current; but I do not know that that has been produced for public illumination; I believe that the waste of electricity would be inordinate with a continuous conductor.

TUESDAY, 29th April, 1879.

MEMBERS PRESENT.

Mr. Adam,	Mr. Arthur Moore,
Mr. Alfred Gathorne-Hardy,	Earl Percy,
Mr. Hardcastle,	Dr. Lyon Playfair,
Mr. Mitchell Henry,	Mr. Puleston,
Mr. Heygate,	Mr. Christopher Talobt,
Lord Lindsay,	Mr. Spencer Stanhope.

The Right Honorable LYON PLAYFAIR, in the Chair.

MR. C. WILLIAM SIEMENS, D. C. L., L. L. D., F. R. S. called in, and examined.

123. CHAIRMAN. You are, I believe, a Fellow of the Royal Society, a Doctor of Civil Law of Oxford, and a Member of the Institute of Civil Engineers?—I am.

124. Have you for a long time interested yourself in the application of electrical science?—Since the year 1848.

125. With what manufacturing firm are you connected, so far as relates to this subject?—With the firm of Siemens Brothers.

126. Messrs. Siemens Brothers have made a large amount of apparatus and wires for telegraphic communication, both by land and by sea, have they not?—They have carried out extensive works, and amongst others the Indo-European line, and the direct United States Sub-marine Cable.

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150. I suppose it would generally follow from that, that not subdividing the electric light, but taking one electric light which your experiments refer to, you would contend that the electric light is economical in regard the amount of energy obtained from the fuel?—It is a very economical mode of producing light.

151. It would be considerably more expensive if your light was subdivided into various lights?—The consumption of energy increases in a very rapid ratio, inversely as the concentration of the light. In dividing the light into two lights each will probably not give more than one-fourth of the effect.

152. Very nearly according to the squares or more than the squares?—I think it is more than the squares. Exact experiments are wanting on this subject; but so far as observations have led me to come to a conclusion, I should say that it increases in a more rapid ratio than the squares.

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259. Has your attention been called to some of the more recent experiments of Mr. Edison, and to the success which he is stated to have achieved in subdividing the light, and making it applicable for rooms and dwellings, and so on, with great ease and cheapness?—I have, and I think Mr. Edison can, no doubt, produce by his means a very steady and possibly an agreeable light.

260. And a cheap light he claims, I believe?—Dynamically speaking, I think, he has to prove his case as yet. Our experience, as far as I can judge from my own, leads me to an opposite conclusion.

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MR. CONRAD WILLIAM COOKE, called in, and examined:

318. (Chairman). You are a civil and consulting engineer, are you not?—I am.

319. You are a member of the Society of Telegraph

Engineers, and of the Physical Society of London, I believe?—I am.

320. Were you formerly engaged in any engineering firm?—I was a partner in the firm of Whieldon & Cooke, electrical and general engineers.

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333. Have you not, during the last few years, given great attention to the progress of invention with regard to the electric light?—Yes, I have made it a special study from my first connection with it. I have taken a great interest in it, and I have also done so with regard to contributing to the literature of the subject, and preparing descriptions which have appeared in the scientific journals, some of which I have here.

334. Especially in the journal called "Engineering"?—Yes; there are in "Engineering" probably twenty or thirty descriptions of all the systems, and I think they have all, with one or two exceptions, been written by myself.

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FRIDAY, 2d May, 1879.

MEMBERS PRESENT.

Mr. Mitchell Henry,	Dr. Lyon Playfair,
Sir Ughtred Kay-Shuttleworth,	Mr. Puleston,
Lord Lindsay,	Mr. Spencer Stanhope,
Mr. Arthur Moore,	Sir David Wedderburn,
	Earl Percy.

The Right Honorable LYON PLAYFAIR in the Chair.

Mr. CONRAD W. COOKE recalled, and further examined.

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388. Have you given attention to the question of obtaining light by means of incandescence, necessitating

a closed circuit?—I cannot speak with any practical experience of that. My view of it is that you would have a far greater loss. It could not be done so economically, but it would probably be applicable in cases where economy was not so much an object, and where there was some special reason for dividing it.

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399. I suppose we may assume that the lighting of large areas can be done satisfactorily, and without excessive cost, by means of the electric light?—Yes, I think that the lighting of large areas, such as squares and buildings and large halls, by the electric light, would give a decidedly economical result.

400. But your answer would not be so decided with regard to small places and with regard to domestic illumination?—No, not in the present state of the science.

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420. Dr. Siemens, in his evidence, stated that the light should be centralized rather than subdivided. Do you concur in that view?—That is what I meant.

421. Is it not desirable that it should be subdivided?—It is very desirable, for illuminating purposes, that you should distribute your lights in a great many places; but the moment you divide your current, at each point of division you lose a certain amount. In fact, you might almost compare it to changing money where you have to pay commission at each change.

422. I suppose that the fact that it cannot be subdivided is one of the difficulties in its practical use now?—That is one of the great difficulties in street illumination, and it is the insuperable difficulty at present as regards domestic illumination; but for the illumination of large halls and large areas I think that centralization is better than subdivision.

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425. Dr. Siemens, in referring to Mr. Edison, who is credited with having recently invented a machine for subdividing the light, expressed some doubt on the subject, and stated that he thought it was not as promising as the reports indicated; do you know any-

thing about that?—We really know very little at all about it. A few newspaper paragraphs have appeared on the subject, and I have been very much interested, as everybody has. His nephew told me, himself, that he has seen, I think, over 200 lights in one circuit. I must say I should like to see it myself, and that is all that I can say.

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Mr. William Henry Preece, called in and examined:

503. What position do you hold in the post-office? I am electrician to the post office.

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510. I think you have both considered and made experiments upon the subdivision of the electric current for the production of various lights?—I have; I have examined the questions theoretically from a mathematical point of view, and I have also examined it experimentally.

511. Did you not publish a paper upon the subject in the January number of the "Philosophical Magazine"?—I did.

512. What was the result that you came to?—In that paper I showed, first of all, that there are two ways of subdividing the light. Supposing that this piece of string which I hold in my hands were a wire conveying the current, we might insert in that one string several lamps, or we might take these several lamps and join them up in what is called a parallel arc. You may have your wires arranged parallel with each other, with one lamp in each. The result of my inquiry was to show that when lamps are joined up in series, the intensity of light in each lamp diminishes with the square of the number inserted; and when they are joined up in this parallel arc, the intensity of light diminishes as the cube of the number, showing, that when you attempt to subdivide the light beyond two or three, intensity of the light diminishes in a marvelous ratio.

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515. Then, according to your view, the electric light is really very economical when it is used for giving central lights, but not when it is used in a subdivided form?—It is only economical wwhen one machine is used to produce a single light.

316. And any departure from that means waste, economically speaking? Certainly.

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Friday, 9th May, 1879.

Members Present.

Mr. Alfred Gathorne Hardy,
Mr. Hardcastle,
Mr. Mitchell Henry,
Sir Ughtred Kay-Shuttleworth,
Mr. Arthur Moore,
Earl Percy,
Dr. Lyon Playfair,
Mr. Puleston,
Mr. Spencer Stanhope,
Mr. Christopher Talbot,
Sir David Wedderburn.

The Right Honourable Lyon Playfair, in the Chair

Mr. John Hopkinson, D. SC., F. R. S., called in, and examined.

586. Chairman: You are a fellow of the Royal Society, I believe? Yes.

587. And a Doctor of Science of the University of London? Yes.

588. Have you, as a civil engineer, paid attention to the electric light, and to lighthouses? I have for the last seven years been engaged in the construction of lighthouses, and consequently I have taken great interest in the subject of eletric lighting.

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624. There is positively, however, in practical working, a loss of economy in dividing the current into several electric lights; what, in your opinion, is the cause of that waste? I think it is really twofold. In the first place you have, in these divided lights, generally much smaller lights than the full light; and for the reason which has been already mentioned, of a lower

temperature, you will, therefore, get a less proportion of radiation sensible to the eye. That point has been very well illustrated by some experiments of Captain Abney's which were published in the proceedings of the Royal Society about a year ago. He shows by measuring the lights of electric arcs of different sizes that the powerful lights contain a much larger proportion of blue light than the weaker ones. For example (I will give the figures as best I can from memory), he had in one case an electric arc which gave about 180 times as much red light as a candle, but it gave 360 times as much blue light. Then he ran the machine faster, and obtained a more powerful light; and, if I remember rightly, it was something between 2,000 and 3,000 times as much red light as a candle, and over 10,000 times as much blue light.

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650. (Sir *Ughtred Kay-Shuttleworth.*) As I understand it, the real expense of the iridium light consists in this, that the iridium being a continuous conductor, there is great waste of power in the consequent flow of electricity from which you are getting no light? The real loss in these incandescent lamps lies in this, that the temperature cannot be driven to so high a point as when the electric arc is used; but not even iridium, which has, perhaps, the highest fusing point of any metal, will stand the temperature of the electric arc without melting or being volatilized.

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Friday, 23d May, 1879.

Members Present.

Mr. Alfred Gathorne Hardy,	Dr. Lyon Playfair,
Mr. Hardcastle,	Mr. Puleston,
Mr. Mitchell Henry,	Mr. Spencer Stanhope,
Lord Lindsay,	Mr. Christopher Talbot,
Mr. Arthur Moore,	Sir David Wedderburn.

The Right Honorable Lyon Playfair in the chair.

Sir *William Thomson*, LLD., D.C.L., called in and examined.

1742. Chairman: We do not require to ask you who you are, but perhaps you will allow me to ask you formally whether you are Professor of Natural Philosophy in the University of Glasgow? I am.

1743. You have been lately President of the Royal Society of Edinburgh, have you not? I was president for five years, and I retired in due course at the beginning of the present session.

1744. You are a Fellow of St. Peter's College, Cambridge? Yes.

1745. You have devoted much time, have you not, not only to electricity as a science, but to the application of electricity to practical purposes? I have.

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1779. Would you allow me to ask you about the division of the electric light into various small lights: scientifically do you agree with calculations, the result of which have been put before us, that the effect of a division must be, in some cases, to decrease the light so divided, according to the squares, or according to the cubes of the distance? We have no scientific law of the economy of the electric light in different degrees of division and concentration; but practice and theoretical guesses seem to agree in making the economy much less when we spend the same quantity of energy, for example, in ten feebler lights than when we spent it in one strong light; when we do this we do not get nearly one-tenth part of the whole light by any of the plans hitherto in use.

1780. But there is nothing in the mathematical discussion of the question that should render that reduction necessarily by the square or the cubes? No; it is quite possible that a plan of using electric energy for light might be found and may yet be found, in which ten feebler lights will give a sum of light equal to that obtainable by the same energy in one concentrated light.

Complainant's Exhibit "Thomson-Houston Vibrating Lamp Article No. 1, of October, 1878." S. M. H., Exr.

JOURNAL OF THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA.
Vol. CVI. October, 1878. No. 4.
(Vol. LXXVI. Third Series.)

A NEW SYSTEM OF ELECTRIC LIGHTING.

By Profs. ELIHU THOMSON and EDWIN J. HOUSTON, of the Philadelphia Central High School.

Having been engaged in an extended series of experimental researches on dynamo-electric machines, and their application to electric lighting, our attention has been directed to the production of a system, that will permit the use of a feebler current for producing an electric light than that ordinarily required, or, in other words, the use, when required, of a current of insufficient intensity to produce a continuous arc. At the same time, our system permits the use of a powerful current, in such a manner as to operate a considerable number of electric lamps placed in the same circuit.

As is well known, when an electrical current, which flows through a conductor of considerable length, is suddenly broken, a bright flash, called the extra spark, appears at the point of separation. The extra spark will appear, although the current is not sufficient to sustain an arc of any appreciable length at the point of separation.

In our system, one or both of the electrodes, which may be the ordinary carbon electrodes, are caused to vibrate to and from each other. The electrodes are placed at such a distance apart, that in their motion towards each other, they touch; and afterwards recede a distance apart which can be regulated. These motions or vibrations are made to follow one another at such a rate, that the effect of the light produced is continuous; for, as is well known, when flashes of light follow one

another at a rate greater than twenty-five to thirty per second, the effect produced is that of a continuous light. The vibratory motions may be communicated to the electrodes by any suitable device, such, for example, as mechanism operated by a coil spring, a weight, compressed air, etc., but it is evident that the current itself furnishes the most direct method of obtaining such motion, as by the use of an automatic vibrator, or an electric engine.

In practice, instead of vibrating both electrodes, we have found it necessary to give motion to but one, and since the negative electrode may be of such size as to waste very slowly, motion is imparted to it, in preference to the positive. The carbon electrodes may be replaced by those of various substances of sufficient conducting power.

In this system, when desired, an independent battery circuit is employed to control the extinction and lighting of each lamp.

Philadelphia, September 19th, 1878.

Complainant's Exhibit "Thomson-Houston Vibrating Lamp Article No. 2, of October, 1878." S. M. H., Exr.

JOURNAL OF THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

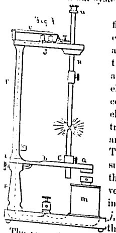
Vol. CVI. October, 1878. No. 4.

(Vol. LXXVI. Third Series.)

A NEW ELECTRIC LAMP.

By Profs. ELIHU THOMSON and EDWIN J. HOUSTON, of the Philadelphia Central High School.

The following is a description of one of the forms of electric lamp which we have devised, to be used in connection with our system of electric lighting:



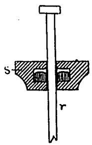
A flexible bar, *b*, of metal is firmly attached at one of its ends to a pillar, *p*, and bears at its other end an iron armature, *a*, placed opposite the adjustable pole-piece of the electromagnet, *m*. A metal collar, *c*, supports the negative electrode, the positive electrode being supported by an arm, *j*, attached to thepillar, *p*. The pillar, *p*, is divided, by insulation at *i*, into two sections, the upper one of which conveys the current from the binding-post marked +, to the arm *j*, and the rod, *r*, supporting the positive electrode.

The magnet, *m*, is placed as shown by the dotted lines, in the circuit which produces the light. The pillar *p*, is hollow, and has an insulated conducting wire enclosed, which connects the circuit-closer, *v*, to the binding-post, marked —. The current is conveyed to the negative electrode, through *b* and the coils of the magnet *m*. When the electrodes are in contact, the current circulating through *m*, renders it magnetic and attracts the armature, *a*, thus separating the electrodes, when, on the weakening of the current, the elasticity of the rod, *b*, again restores the contact. During the movement of the negative electrode, since it is caused to occur many times per second, the positive electrode, though partially free to fall, cannot follow the rapid motions of the negative electrode; and, therefore, does not rest in permanent contact with it. The slow fall of the positive electrode may be insured either by properly proportioning its weight, or by partly counterpoising it. The positive electrode thus becomes self-feeding.

The rapidity of the movement of the negative carbon may be controlled by means of the rigid bar, *l*, which acts, practically, to shorten or lengthen the part vibrating.

In order to obtain an excellent but free contact of the arm, *j*, with the positive electrode, the rod *r*, made of iron or other suitable metal, passes through a cavity, *s*, Fig. 2, filled with mercury, placed in electrical contact with the arm, *j*. Since the mercury does not wet the metal rod, *r*, and the sides of the opening through which it passes, free movement of the rod is allowed without any escape of the mercury. We believe that this feature could be introduced advantageously into other forms of electric lamps.

Fig 2



In order to prevent a break from occurring in the circuit, when the electrodes are consumed, a button, *e*, is attached to the upper extremity of the rod, *r*, at such a distance that when the carbons are consumed as much as is deemed desirable, it comes into contact with a tripping lever, *t*, which then allows two conducting plugs, attached to the bar, *v*, to fall into their respective mercury cups, attached, respectively, to the positive and negative binding-posts by a direct wire. This action practically cuts the lamp out of the circuit.

Philadelphia, September 19th, 1878.

Complainant's Exhibit "Thomson-Houston Vibrating Lamp Article of January, 1879." S. M. H., Exr.

JOURNAL OF THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

Vol. CVII. January, 1879. No. 1.

(Vol. LXXVII. Third Series.)

INDUCTION APPARATUS FOR REVERSED CURRENTS.

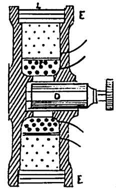
By Profs. ELIHU THOMSON AND EDWIN J. HOUSTON.

The following apparatus was devised by the authors for the purpose of obtaining induced reversed currents for use in electric illumination. These currents we used with a vibrating lamp, a description of which has already been published.

Our method of operation is as follows: A reversed primary current is caused to induce reversed secondary currents in secondary coils provided therefor. These secondary currents are caused to give vibrations to carbon electrodes, and thereby at the same time produce a partial arc between them with sufficient strength of primary current, a considerable number of secondary currents are obtained, each of which is able to operate one of our vibrating lamps.

The use of a vibrating lamp admits of a wide range in the size of the currents employed. When a light of very moderate intensity is desired, the carbons are made of very small size, and are placed in a closed glass vessel for protection from the atmosphere.

To moderate the brilliancy opalescent glass is used. To obtain the highest efficiency of inductive action from a set of primary coils, the following form of induction coil was devised.



The primary coil P, surrounding the core C, is provided with a secondary coil S, adjacent to it. The ends E and F of the bobbin are made of discs of iron concentric with the core C, and slit from center to circumference. The outer extremities of these discs are connected by wires or sheets of iron L to one another forming in this manner an induction coil encased in iron or one whose core has its north and south extremities totally connected. The strength of the current developed in the secondary coil is greatest when the core C, which is movable, is inserted so that both of its extremities are in contact with E and F. By withdrawing this core, the current from the secondary coil may be weakened to almost any desired extent. This coil is best adapted to the use of primary currents, whose direction is constantly changing. All the wire being completely surrounded by iron, whose direction of magnetic polarization is also changed, the highest inductive effect is thereby produced in the secondary coil.

The variations in the intensity of the induced currents will of course be followed by variations in the intensity of the light emitted by the lamp. The movement of the core may, therefore, be made to increase or decrease the intensity of the light.

Complainant's Exhibit "Thomson-Houston Paper on Dynamo Efficiency of January, 1879." S. M. H., Exr.

THE TELEGRAPHIC JOURNAL AND ELECTRICAL REVIEW.

Vol. VII. January—December, 1879.

London. Haughton & Company.

January 15, 1879, p. 25.

Circumstances Influencing the Efficiency of Dynamo-Electric Machines.*

By Profs. Edwin J. Houston and Elihu Thomson.

During the recent competitive trials made at the Franklin Institute as to the relative efficiency of some different forms of dynamo-electric machines, the authors have been entrusted with the work of determining the relations between the mechanical power consumed, and the electric and thermic effects produced, took the opportunity thus afforded, to make a careful study of many interesting circumstances which influence the efficiency of these machines.

It is proposed in the present paper to select from the many circumstances thus noticed, a few of the more interesting, reserving the others for a future consideration.

It will readily be understood from the comparatively new field in which we had been working, no reliable data of the electrical work of these machines having before been obtained, that difficulties constantly arose owing to necessary conditions of operation, and new developments as to the behavior of the machines under varied conditions, were constantly met.

A convenient arrangement of the particular circumstances we are about to discuss may be, 1st. Those affecting the internal work of the machine. 2d. Those affecting the external work, and 3d. The relations between the internal and external work.

The mechanical energy employed to give motion to a dynamo-electric machine is expended in two ways, viz.: 1st. In overcoming friction and the resistance of the air; and, 2d. In moving the armature of the machine through the magnetic field, the latter of course constituting solely the energy available for producing the electrical current. The greatest amount of power expended in the first way was noticed to be about 17 per cent. of the total power employed. This expenditure was clearly traceable to the high speed acquired by the machine. The speed, therefore, required to properly operate a machine is an important factor in ascertaining its efficiency.

The above percentage of loss may not appear so great, but when it is compared with the total work done in the arc, as heat, constituting as it did in this particular instance over 50 per cent. of the latter, and about 33 per cent. of the total work of the circuit, its influence is not to be disregarded.

In another instance, the work consumed as friction was equal to about 80 per cent. of that appearing in the arc as heat, while in the Gramme machine experimented with, this percentage fell to 20 per cent. of that which appeared in the arc as heat, and was only about 7 per cent. of the total power consumed in driving the machine.

In regard to the second way in which mechanical energy is consumed, viz., in overcoming the resistance necessary to move the armature through the magnetic field, or in other words, to produce electrical current, it must not be supposed that all this electrical work appears in the circuit of the machine, since a considerable portion is expended in producing what we term the local action of the machine, that is local circuits in the conducting masses of metal, other than the wire, composing the machine.

The following instances of the relation between the

* Paper read before the American Philosophical Society, Nov. 1st, 1878.

actual work of the circuit, and that expended in local action, will show that this latter is in no wise to be neglected. In one instance an amount of power somewhat more than double the total work of the circuit was thus expended. In this instance, also, it constituted more than five times the total amount of power utilized in the arc for the production of light. In another instance it constituted less than one-third the total work of the circuit, and somewhat more than one-half the work in the arc.

Of course work expended in local action is simply thrown away, since it adds only to the heating of the machine. And since the latter increases its electrical resistance, it is doubly injurious.

The local action of dynamo-electric machines is analogous to the local action of a battery, and is equally injurious in its effects upon the available current.

Again, in regard to the internal work of a machine, since all this is eventually reduced to heat in the machine, the temperature during running must continually rise until the loss by radiation and convection into the surrounding air, are eventually equal to the production, and the machine will at last acquire a constant temperature. This temperature, however, will differ in different machines according to their construction, and to the power expended in producing the internal work, being, of course, higher when the power expended in producing the internal work is proportionally high.

If, therefore, a machine during running acquires a high temperature when a proper external resistance is employed, its efficiency will be low. But it should not be supposed that because a machine when run without external resistance, that is, on short circuit, heats rapidly, that inefficiency is shown thereby. On the contrary, should a machine remain comparatively cool when a proper external resistance is employed, and heat greatly when put on short circuit, these conditions should be regarded as an index of its efficiency.

As a rule the internal resistance of dynamo-electric machines is so low that to replace them by a battery,

the latter, to posses an equal internal resistance, would have to be made of very large dimensions, so that the efficiency of dynamo-electric machines cannot be stated in terms of battery cells as ordinarily constructed.

In regard to the second division, viz., the external work of the the machine, this may be applied in the production of light, heat, electrolysis, magnetism, &c.

Where it is desired to produce light, the external resistance is generally that of an arc formed between two carbon electrodes; the resistance of the arc is, therefore, an important factor in determining the efficiency. To realize the greatest economy, the resistance of the arc should be low, but, nevertheless, should constitute the greater part of the entire circuit resistance.

In some of our measurements the resistance of the arc was surprisingly low, being in one instance .54 ohm, and in another .79 ohm. It was, however, in some instances as high as 3.18 ohms.

It may be noted as an interesting fact that where the greatest current was flowing, the resistance of the arc thereby produced was low. This is undoubtedly due to higher temperature and increased vaporization from the carbons. In this latter case also the greatest amount of light was produced.

The amount of work appearing in the arc as measured by the number of foot pounds equivalent thereto, is not necessarily an index of the lighting power. In two instances of measurement the amount of energy thus appearing in the arc was equal, while the lighting powers were proportionately as three to four. This apparent *anomaly* is explained by considering the resistance of the arc, it being much less in the case in which the greater light was produced. The heat in this case being evolved in less space, the temperature of the carbons, and therefore their light-giving powers, was considerably increased.

A few remarks on the economical production of light from an electrical current may not be out of place. The light emitted by an incandescent solid will increase as its temperature is increased. In the voltaic arc the limit to increase of temperature is in the too rapid vaporization of the carbon. Before this point is reached, however, the temperature is such that the light emitted is exceedingly intense. No reliable method of measuring the temperature of the arc has as yet been found.

A well-known method of obtaining light from electrical currents is by constructing a resistance of some material such as platinum, having a high fusing point and heated to incandescence by the passage of a current. When platinum is employed the limit to its increase of temperature is the fusing point of the platinum, which is unquestionably but a fraction of the temperature required to vaporize carbon. Were the falling off in the amount of light emitted merely proportional to the decrease in temperature, the method last described might be economical. Unfortunately, however, for this method, many facts show that the decrease in the light emitted is far greater than the decrease of the temperature. Most solids may be heated to 1000° F. without practically emitting light. At 2000° F. the light emitted is such that the body is said to be at a bright red. At 4000° F. the amount of light will have increased far more than twice; probably as much as four times that emitted at 2000° F. It is reasonable to suppose that with a further increase of temperature the same ratio of increase will be observed, the proportionate increase in luminous intensity far exceeding the increase in temperature.

It would, therefore, appear that the employment of a resistance of platinum or other similar substance, whose temperature of alteration of state as compared with that of carbon is low, must be far less economical than the employment of the arc itself, which, as now produced, has been estimated as about two or three times less expensive than gas.

Indeed, it would seem that future improvements in obtaining light from electrical currents will rather be by the use of a sufficient resistance, in the most limited

space practicable, thereby obtaining in such space the highest possible temperature.

Perhaps the highest estimate that can be given of the efficiency of dynamo-electric machines, as ordinarily used, is not over 50 per cent. Our measurements have not given more than 38 per cent. Future improvements may increase this proportion. Since the efficiency of an ordinary steam-engine and boiler in utilizing the heat of the fuel is probably overestimated at 20 per cent., the apparent maximum percentage of heat that could be recovered from the current developed in a dynamo-electric machine would be overestimated at 10 per cent. The economical heating of buildings by means of electricity may, therefore, be regarded as totally impracticable.

Attention has long ago been directed to the use of dynamo-electric machines for the conveyance of power. Their employment for this purpose would indeed seem to be quite promising. Since, in this case, one machine is employed to produce electrical currents, to be reconverted into mechanical force by another machine, the question of economy rests in the perfection of the machines and in their relative resistances.

In respect to the relations that should exist between the external and internal work of dynamo-electric machines, it will be found that the greatest efficiency will, of course, exist where the external work is much greater than the internal work, and this will be proportionately greater as the external resistance is greater. Our measurements gave in one instance the relation of .82 ohm of the arc to .49 ohm of the machine—a condition which indicates economy in working. The other extreme was found in an instance where the resistance of the arc was 1.98 ohms, while that of the machine was 4.60 ohms—a condition indicating wastefulness of power.

Complainant's Exhibit Morton's Government Report. S. M. H., Exr.

REPORTS

ON

THE TOPOPHONE

AND

THE ELECTRIC LIGHT

BY

PROF. HENRY MORTON

MEMBER OF THE LIGHT-HOUSE BOARD.

Being the Appendix to the Annual Report of the Board for the Year ending June 30, 1879.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1880.

* * * * * *

REPORT ON EXPERIMENTS WITH MACHINES FOR PRODUCING ELECTRIC LIGHT.

HOBOKEN, N. J., November 29, 1879.

SIR—In pursuance of the suggestion of your letter of October 30, I have carried out a number of experiments with various machines for producing powerful electric currents, and with various forms of "electric regulators" or "electric lamps," by which such currents

may be utilized in the production of a brilliant source of light.

In order that the whole subject may be made plain in all its relations, I have thought it best to begin my report with a general discussion of the principles on which all such machines are founded, and a knowledge of which is important for their successful management.

In the first place, an electric light is some source of light developed by electricity, and as there are three distinct methods by which electricity may be caused to develop light, we have naturally three distinct sorts of electric light.

Naming these in the order of their intensity, they are:

The electric arc;
Ignited conductors;
Incandescent gases.
These I will briefly explain in their order.

* * * * * *

INCANDESCENT CONDUCTORS.

In some of the early experiments of Sir Humphrey Davy we find mention of the heating to luminosity of wires of various metals, as tests of the comparative power of different batteries; and, in 1858, so great an advance had been made in the practical utilization of this means of lighting, that M. Jobart, in a report to the Academy of Sciences at Paris, was able to speak as follows:

> "I hasten to announce to the academy the important discovery of the dividing of an electric current for lighting purposes. This current, from a single source, traverses as many wires as may be desired, and gives a series of lights ranging from a night lamp to a light-house lamp.
>
> "The luminous arc between the carbons produces, as is well known, a very intense, flickering and costly light. M. de Changy, who is a chemist,

mechanician and physicist, is thoroughly conversant with the latest discoveries, and has just solved the problem of dividing the electric light.

"In his laboratory, where he has worked alone for the past six years, I saw a battery of twelve Bunsen elements producing a constant luminous arc between two carbons, in a regulator of his own invention, this regulator being the most simple and perfect I have ever seen. A dozen small miners' lamps were also in the circuit, and he could at pleasure light or extinguish either one or the other, or all together, without diminishing or increasing the intensity of the light through the extinction of the neighboring lamps. The lamps, which are closed in hermetically sealed glass tubes, are intended for the lighting of mines in which there is fire-damp, and for the street lamps, which would by this system be all lighted or put out at the same time, on the circuits being opened or closed. The light is as white and pure as Gillard's gas, with which it has one point in common, namely, its production by the incandescence of platinum. The gas pipes are replaced by simple wires, and no explosions, bad smells or fires can take place.

"The trials that have been hitherto made, with the object of producing an electric light by means of heated platinum, have failed on account of the melting of the wires. This difficulty has been overcome by M. de Changy's dividing regulator. The cost of the light is estimated to be half that of gas. A lamp placed at the mast-head of a ship would form a permanent signal for about six months without the necessity of changing the platinum. With several such lights placed in tubes of colored glass it would be easy to telegraph by night, as they could be extinguished and relighted rapidly from the deck.

"For light-house purposes considerable amplitude can be given to the light. I also saw a lamp so arranged in a thick glass globe that it could be immersed to considerable depths without being extinguished by any movement. This lamp has already been used in the taking of fish which were attracted toward the light.

"The above slight description will suffice to show to what a variety of applications this discovery can be put. The communication which I have had the honor of laying before the academy is founded upon no illusion; a lamp was, to my astonishment, lit in the hollow of my hand, and remained alight after I had put it in my pocket with my handkerchief over it."

In the *Comptes Rendus*, or minutes of the French Academy, I find that the communication of M. Jobart was received at the meeting held March 1, 1858, and was referred to M. Becquerel. At a meeting of April 5th, M. Becquerel reported that he did not find anything sufficiently definite to warrant the Academy to express an opinion as to the importance of this discovery, "All that was desirable at present was fuller information." At the meeting of April 19th, M. Jobart responds to this request by stating that "he could not give more precise details without exposing the author to see another profit by his discovery."

It would appear as if this brillant and complete success described by M. Jobart as achieved by M. de Changy in Paris, in February, 1858, was very rapidly followed up in this country, for I learn from a letter in the "Salem Observer" of November 2, 1868, that Mr. Moses G. Farmer, in Salem, lit his parlor every evening during July of 1859 with electric lamps operated on a like principle.

Notwithstanding this very promising beginning, however, little or no progress seems to have been made in this method of lighting for the twenty years intervening between the dates above given and the present time, for we certainly have no system of electric lighting by incandescence superior to that above described, nor has the older one or any of its newer rivals come into any general use. As the reasons of this have a very important bearing on the objects of the present report a few words about them will, I think, be in place here.

The difficulties presented in the problem of producing light by incandescence were:

1. Its watsefulness of the energy employed and conquent costliness.

2. The difficulty caused by the disintegration of the substance heated.

Thus, if platinum was used as the substance to be heated, it was found that heating it as nearly as possibly to its melting point, the amount of electric current which would yield in the arc a light of 1,000 to 2,000 candles would only produce a light of about 50 to 100 candles, and, also, that when the platinum had been thus used it became very brittle and finally broke up.

Small rods of carbon placed in exhausted tubes admitted of higher temperatures, but were quite rapidly consumed, or rather vaporized and disintegrated.

According to the statements recently published by Mr. Edison, it would seem that he has succeeded in reducing platinum to a condition in which it will endure a much higher temperature without fusing, and therefore yield a more economical light, and also remain unaltered indefinitely.

If these statements are confirmed by continued experience, it would seem that the electric light from incandescence would rival that from the "electric arc," and by reason of its convenience and steadiness would supersede it in most cases.

At all events, for light-house use, even if far less economical, such a light would be of great value; and I think that this subject should be carefully investigated before any important steps are taken in the practical application of electricity as a source of light even experimentally in our light-houses.

Though none of them have proved practically useful as yet, nevertheless some notice of methods of lighting by incandescence should be here given historically for future reference.

The first electric lamp operating by incandescence of which we have any actual record seems to be that invented by the American, Starr, a patent for which was

taken out in England by his agent, King, in 1845, and which has thus come to be known as the King lamp. This lamp has been modified in details until it has reached the form shown in Fig. 3, known as the Koun lamp.

(Note. Here is given in the original the same cut as figure 3 of Dr. Morton's "Gaslight Journal" Article).

This apparatus consists of a glass vessel provided with a metal cap and packing-box below, by means of which it can be closed air-tight.

A connector at K allows of the exhaustion of air from the interior, and the filling of the interior with any inactive gas.

Two upright metallic conductors, connected respectively with the two poles of the electric circuit, pass up through this glass vessel, and at their upper ends support, as shown, two or more rods of carbon or other conductors. The electric connection with these rods is made from C by means of the lever I, which communicates first with the longest rod F, and when that is burned up, falls upon the next longest, and so on. The light is produced by the rod of carbon heated white hot by the current.

Various slight modifications of this lamp have been made and elaborately experimented with; but they all show the same essential characteristics.

The first of these is that, as long as any oxygen remains in the vessel, the carbon rods consume rapidly, the first one generally lasting only twenty minutes. The second carbon will, however, last two hours if the light does not exceed forty burners; but even when all active gas has been removed, the carbon suffers a sort of vaporization.

The second characteristic of these incandescent lamps is that, with the same current, they develop much less light than is obtained from the electric arc. Thus, a battery of 48 elements, with a Serrin lamp, gave an electric arc equal to 100 burners; but with one of these lamps gave a light equal only to 80 burners, and when divided between three lamps, gave only the light of 10 burners each.

The third characteristic is the manner in which the light-producing power of the current diminishes as it is distributed between a number of lamps. Thus, the current from a given battery, acting on one lamp, produced a light between four and five burners; on two lamps, a light of 1½ burners each; on three lamps, one-third to two-thirds of a burner each. From another battery, the current on a single lamp gave a light of 11 to 12 burners; with two lamps, one-half burner each; and on three lamps, one-ninth of a burner each.

In another case, a given battery with one lamp gave the light of nine burner; with two lamps, 2¼ burners; and with three lamps, one-third of a burner each. Another battery with one lamp gave a light of 65 burners; with two lamps, 7½ burners; with three lamps, 1⅓ burners; with four lamps, three-fourths of a burner; and with five lamps, one-half burner each.

Another modification of this Starr or Koun lamp is found in that which has been recently exhibited in New York as the Sawyer-Mann lamp.

This differs from the former apparatus in no important feature except that the interior of the vessel is said to be filled with pure nitrogen at the ordinary pressure. The carbon rods are said not to waste away in these lamps. Without knowing anything positively on the subject, my opinion is that this is only because they have not been subjected to strong currents, but have only been heated to the extent of yielding the light of one or two burners. Under these circumstances, the carbons of the Koun lamp will last a long time, but on the other hand, the light so obtained is not economical, as we see above.

When exhibited in New York recently, we understand that five lamps only were operated by a magneto machine of Arnoux & Hochhausen, driven by a three-horse power steam engine, said to be developing only one and one-half horse power.

* * * * * *

Very respectfully,

Henry Morton,

Chairman Committee on Experiments.

The Chairman of the Light House Board.

Complainant's Exhibit Siemens' Paper. S. M. H., Exr.

"Zeitschrift fur Angewandte Elektricitatslehre," Munich 1879. Vol. I., pp. 343–356.

(Translation.)

Electricity in Relation to Life by Dr. Werner Siemens.

* * * but we can I hope even now say with confidence, that with the dynamo electric machine an additional important help is given us for rendering the forces of nature useful in the service of mankind. This appears particularly evident in the progress which electric lighting has made in recent times.

Now there is hardly an important lighthouse built which does not have an electric light. With the electric light, even now, the larger ships seek to distinguish the danger threatening reefs and vessels in their course; with the aid of the same, tow boats are also able to find their way at night in rivers and canals. The electric light already illuminates very many factories, dock-yards and larger halls. It plays an important part in offensive as well as in defensive warfare and has everywhere had a wide application where great clearness, the beauty of the dazzling white light and its comparatively slight heating power, as well as the absence of noxious products of combustion are of the first importance. Up to within a few years however a great obstacle stood in in the way of the more general extension of the electric light—its slight divisibility. It was not possible until then to place more than one arc light in a conductor with safety. This is owing to the reason that the regulation of the mechanism which regulates the distance between the carbon rods, between which the electric light is formed, is effected by the strength of the current, which prevails in the conducting circuit. If the arc light of Davy becomes longer by the burning away of the carbons, then the resistance of the same becomes greater and thereby the strength of the current in the conducting circuit becomes weaker, thereupon causing a corresponding approach of the carbons together by means of the lamp mechanism. Now if there are several arc lights in the same conducting circuit, the strength of the current in the same is dependent upon the sum of the resistances of all the arc lights together, for which reason it remains equal however great the resistance of a single arc light.

The strength of the current then becomes no longer available for the regulation of the length of the arc of the single arc lights. In order to remedy this fault and to make an unlimited subdivision (Theilung) of the electric light possible, very many attempts have been made and up to the most recent time, to make use of thin carbon or metal rods (instead of the arc light), which are made incandescent by the electric current as sources of light. A light so produced however is comparatively very feeble, takes much current, therefore much power and, indeed, is as yet hardly to be called an electric light. Jablochkoff made a first important step in the direction of the subdivision of arc lights.

He placed two small carbon rods side by side and filling up the space between them with plaster of Paris or other difficulty fusible substance. Four to six of such "electric candles" could be placed in a conducting circuit, because the length of the arc in this case was fixed for every one.

In order to obtain an equal consumption of both carbons, alternating currents were used instead of continuous currents for the production of the light, as had already been previously done by the employment of magneto-electric machines for lighting. These "electric candles" have substantially contributed to the extension of electric lighting, but accomplish their purpose but very imperfectly, because all the candles are extinguished if one fails for any reason whatsoever, and because the light does not then automatically relight itself, as is the case in employing electric lamps. It was reserved to the most recent time to obtain the solution of the problem of the subdivision of the electric arc light by the use of

the mechanism regulated by the length of the arc, and thereby to remove the real obstacle, which up to that time stood in the way of the general application of electric lighting.

* * * * * *

(1.) This discourse was intended for the general meeting of the Natural Philosophy Society at Baden-Baden, but by reason of too late announcement could be considered only in the abstract in the Physical Section.

Complainant's Exhibit Chap. III. Bernstein's Book. S. M. H., Exr.

Translation of Chap. III., pp. 70 to 80, of the German work entitled,

" Die Electrische Beleuchtung "(Electric Lighting),

by

Alex. Bernstein, Civil Engineer.

Published in Berlin in 1880, with the preface dated November, 1879.

III.

New Methods of Producing Light.

We have already mentioned in the introduction, that the electric carbon light, in the form in which we have already considered the same, is not the only kind of light which can be produced by the aid of electricity; there is also another kind of electric lighting to be mentioned in a few words. Up to this time, however, applications to practice with favorable result, have only been made with the arc light, which originates between two carbon rods in the manner described by us, while all other systems are still in the experimental stage.

In order, however, to give as complete an idea as possible of the present situation of electric lighting, other methods of producing light, and especially the more recent efforts in this direction, ought also to be briefly mentioned at this point.

If the two carbon rods in a regulator are in contact with each other, and an electric current flow through them, both carbon rods begin to glow at the point of contact and give out light. The phenomenon happens in a little different form if a thick piece of carbon is substituted for one rod and a thin pencil of carbon for the other rod, which rests upon the piece of carbon just mentioned. Then all the light is concentrated at the point of the thin carbon pencil from which will radiate a sparkling light. This phenomenon has been made the foundation of several types of lamps.

Fig. 14 (p. 72) shows the lamp made by Werdermann in London.

The carbon block is seen above, the cross-section of which is 64 times greater than the cross-section of the thin carbon rod placed below it, which is pressed upwards by a weight, moving in the long cylindrical tube, by means of the use of grooved pulleys and cords (Schnurrollen).

Now, if the light is thus radiated only from the point of the thin carbon rod, a wasting away of the upper plate also takes place, and the carbon rod works itself into this plate; for this reason, after some time, there must be another point of contact.

In order to effect this automatically with the lamp, Reynier, in the construction shown in Fig. 15 (p. 72), makes use of an easily turning carbon wheel. The thin carbon rod, lying a little off the centre, by means of its weight, causes a revolution of the wheel, corresponding to its wear, whereby a continued renewal of the points of contact takes place. An entirely similar construction was almost simultaneously made public by Marcus in Vienna.

The results which have been obtained with these contact lamps, up to this time cannot be considered as satisfactory. They operate generally only for a short time without trouble, and, in reference to economy, have likewise no especially favorable figures to show. There is however an advantage in that, with sufficient current strength, a large number of these lamps can be placed in one circuit, the illuminating power of which is stated to be from 50 to 100 candles.

In experiments made in Paris not long ago, five lamps were placed in one circuit, under which condition the light of each lamp measured 120 units, so that the total quantity of light amounted to 600 units. On the other hand, when ten lamps were applied, the light of each lamp amounted to 40 units, and the total result therefore was equal to 400 units. The motive power necessary for their operation is not given herewith, but in all probability it was at all events, not less than 2½ horse-power.

Up to this point, we have always assumed the use of two pieces of carbon for the production of the electric light; the employing of two pieces however is not absolutely necessary. If, in a circuit which offers a small resistance to the current, a very fine carbon pencil is placed, a luminosity of the carbon pencil must be the consequence, because of the high resistance of the pencil and the great heating occurring on this account. This fact has likewise been made use of in the construction of lamps, in reference to which the unpleasant question of priority has often been raised. This question of merit—taken here in its scientific sense ought to be changed, for in answering it not one name but several are to be mentioned. Here, in this case as we have done in all which has preceded, we allow the question of priority to remain entirely undetermined, merely stating that King, an Englishman, in the year 1845, and Lodyguine, a Russian, in 1873, have constructed lamps of this kind, upon which, later, several improvements have been made by others. The disadvantage of all these lamps lies in the fact that the thin carbon pencil has only a very short life and soon breaks at the weakest point. It is likewise naturally obvious that the carbon pencil is very quickly consumed in the air.

To remedy this evil, the carbon pencil has been enclosed in an air tight glass bell, and later on this has been filled with gases which prevent combustion. But it appears that at a white heat the electric current causes small particles to be thrown off from the carbon pencils obtainable, and thus also in this case a pretty rapid wearing-out takes place. At all events, the results up to this time do not yet sound very encouraging. In place of the carbon pencils, any other body can of course be employed, which is able to withstand a high degree of heat without chemical change, and which can be placed in the circuit in a form in which it opposes a suitable resistance to the passage of the current.

rent. Thin metallic wires are especially suited to this purpose, and among them, a thin platinum wire is particularly adapted to this end.

Thus we come to that form of electric lighting which has been particularly associated with the name of Edison, although the system itself was known even earlier, before Edison had yet occupied himself with this matter, and the known forms of construction made by this inventor up to this time do not yet by far merit the seal of success.

It is a known fact, that all solid bodies begin to glow by a heating of about 1,000°, and indeed with reddish light. By raising the temperature, the color changes and the amount of light increases; at 1,300° the light becomes yellow, at 1,500° blue, at about 2,000° all colors of the spectrum are produced, and a white light is obtained. Few bodies, however, bear this degree of heat without being destroyed, among such are platinum, iridium and osmium.

If the heating is carried still higher, the quantity of radiated light increases in increased proportion. Thus the platinum at 2,600° is said to develop a light which is 40 times as intense as when at a temperature 1,900°. But at the high temperature, the application of which is advantageous, danger of immediately destroying the platinum is incurred.

The manner in which Edison seeks to overcome this danger is seen in the drawing Fig. 16 (p. 76).

Upon a hollow stand is placed a case of moderate length in which the regulating lever *s*, free to move upon the axis *o*, is placed. This lever is supported by the rod *x*; as soon as the latter expands by strong heating the lever *s* touches the screw *v* and thus comes in electrical contact with the metal piece *i*. Above the case is placed a glass cylinder, in the centre of which the luminous platinum spiral *a* is placed.

The current passes from the binding post *n* through the wire P into the lever *s*, through the rod *x* and into the cap of the glass cylinder into the wire *m*; then to the right hand binding-post in the glass cylinder, through the platinum spiral, into the left hand binding-post; thence to the metal piece *i* and through the wire *m* to the binding-post *k*. But as soon as the rod *x* has increased in length by a fixed amount, in consequence of the too great heating by the current itself and by the radiation from the platinum spiral, the lever *s* comes in contact with the screw *v* and offers to the current a direct path of very low resistance from *p* through *s* and *i* to *n*.

The spiral which now receives almost no current, parts with its heat, the rod *x* contracts, and the current again flows through the spiral.

The apparatus may work very well in a laboratory; but its practical utility has not been demonstrated by experience.

Moreover an objection here presents itself, to which little thought had previously been given. It was generally supposed that platinum does not alter by heat; Edison, however, found by his researches, that the surface of the platinum wire in time becomes full of small cracks, and the platinum then appears to be able to offer little resistance to the heat. Edison attributes the reason for the origin of these cracks in the great amount of air which the platinum ordinarily contains. Now in order to expel the air, he proceeds as follows: The wire within the glass bell of an air pump is heated by an electric current and the air is then pumped out; this process is repeated several times. Edison maintains that then the platinum obtains a great density and withstands a much higher degree of heat with durability. It is, however, to be supposed that, in time, the air will again be absorbed by the metal.

With wires prepared in this manner, Edison says he has lately obtained the following result.

Eight spirals were placed in one circuit, every one of which produced a light of 13 units, so that the total quantity of light amounted to 104 units. One horse-power was necessary for their maintainance.

We certainly wish for this indefatigable inventor, that his interesting experiment may lead to a profitable result.

We come to the end.

We have considered at length the electric light in the form of the so-called voltaic arc light, which was exhibited for the first time by Davy of England in the year 1813. With regard to construction, this form is characterized by the light being principally radiated from the oppositely lying ends of two carbon rods. The arc, lying between both carbon rods, is not the chief source of light, as it is incorrectly stated in many text-books. In reference to the effect, it appears that this construction is especially adapted to the production of very intense sources of light. With an expenditure of 4 horse-power, a light effect of 4,000 units is obtained or a light of 1,000 standard candles per horse-power. Then we have considered the Jablochkoff candle in detail, as a special type for the application of the arc light, and have found that it requires about 1 horse-power for its operation and produces a light of almost 400 units.

The application of the electric light by means of the arc light, alone has claim to be considered in detail, for the reason that this application is confined to it alone of which, up to this time, very successful practical use has been made. We have finally also briefly mentioned the methods of production by feeble sources of light, which are intended to supplant gas. It is supposed, that in the contact-lamps, in which a thin carbon rod is brought in contact with a thick piece of carbon, a light of about 200 units is generated with the consumption of one horse-power, and that the figures before stated are to be considered as approximately correct; while Edison, in his lamps in which an incandescent platinum wire is the source of light, obtains a total amount of light of 104 units with the consumption of the same power. Thus the closer we approach to those systems, which permit a division of the total amount of light into many feeble light centres, the more unfavorable becomes the ratio between the power required and the light produced. Add to this, that the expense of the carbon rods for the feeble light in relation to the total amount of light produced, is considerably greater than is the case with the powerful light.

For these reasons, we arrive at the result that a limit to the subdivision of the light is imposed by the known forms of electrical carbon-lights, which cannot be overstepped without the excessive cost of operation appearing as a substantial loss.

The feeble electric light has much better prospects if we succeed in obtaining a metallic wire, which, by standing a very high heat, is therefore little inclined to destruction, and when the necessary devices are found for preventing this destruction by means of an accurate regulation of the strength of the current. It may be remarked here, that an important piece of apparatus for the purpose of regulating the strength of the current, has been lately constructed by William Siemens in London.

If we succeed in overcoming the objections, the electric light of this type has a very important future in those parts of the earth in which motive power is abundantly and cheaply at hand.

At present we must be content to make use of electric lighting by means of an intense light unless the properties of the electric light, which we have considered in detail, yield additional advantage under other conditions.

The examples cited can, indeed, serve as proof that, even in the present form, there is a wide field of application for the electric light.

It is likewise to be hoped that the important advance, which electric lighting has acquired in recent years, will serve to extend this form of lighting to an increased extent; for the practical applications lead to progress in the art.

Complainant's Exhibit, Trant Letter.— S. M. H., Ex'r.

[*"Nature," Vol. 19, London, Nov. 21, 1879, page 52.*]

The Divisibility of the Electric Light.

The English and American periodicals devoted to electrical science now announce "on authority," that the electric light discovered by Edison is a light by incandescence. If this be true there is nothing new or startling either in the discovery of the light or of its divisibility. Lighting by incandescence has been studied for a long time; indeed, it has been studied much more thoroughly than any other kind of electric lighting. Thirty-three years ago a method of producing and subdividing the light was patented in England by a Mr. King. The light was produced by heating to white heat in a vacuum, by means of the electric current, either platinum or carbons; and, the specification adds, "when the current is of sufficient intensity, two or a larger number of lights may be placed in the same circuit." For some years after this discovery several improvements on King's invention were patented in America, France and England; "but," says M. Fontaine, "none of these appear more complete, more explicit and more practicable than King's; it is, then, useless to continue our nomenclature." The principle of lighting by incandescence, although not neglected or forgotten, seems to have made but little progress until 1871, when M. Lodyguine showed an experiment in the Admiralty Dockyard in St. Petersburg, when he divided the circuit into no less than two hundred lights. This naturally made a great sensation at the time—as great a sensation as that caused by Mr. Edison's telegram of the 7th ulto. The Academy of Science awarded to M. Lodyguine the large Lomonossow prize of 50,000 roubles. A company was formed in St. Petersburg with a capital of 200,000 roubles, and the excitement in Europe was then almost as great as has been witnessed in England lately. It was soon found, however, that Lodyguine's discoveries, like those of his predecessors in the same field, were, after all, impracticable, and that this illimitable division of the light, however ingenious, was only a fanciful experiment. Every penny subscribed to the company referred to was lost, and Lodyguine's great discovery is now, where it was then, in his laboratory.

It has, however, been urged that these early inventors of the electric light knew only of the galvanic battery as a generator of a powerful current, and that had they known of the Gramme machine or other dynamo or magneto-electric machine, the results might have been different. The remark, however only applies to King and the improvers who immediately succeeded him. The great division of the light by Lodyguine, to which reference has just been made, was in a circuit produced by two "Alliance" machines. Even, however, if such were not the case, there are at present before the world, in more or less detail, four recent inventions for the production of a divided light by incandescence. These are the inventions of M. Reynier, of M. Arnaud, of Mr. Edison, and most recent of all, M. Werdermann. From the way in which these discoveries, if they are discoveries, have been ushered into the world, it is found that great claims are made on their behalf, and there are, therefore, naturally great expectations on the part of the public in regard to them. It cannot be urged now in mitigation of the shortcomings of the incandescent light, as it has been urged in the past, that it has not had a fair trial, on the ground that the lamps in existence were imperfect in conception, and complex in construction. The lamp of M. Reynier seems admirable in its way, and if light by incandescence were to be the light of the future, the claims of this lamp would have to be very carefully considered, and, in any case, it will certainly hold an important place in all investigations into the subject. The lamp of M. Werdermann appears to be identical in principle with, and only

slightly different in detail from, that of M. Reynier, and we may fully expect that these inventors will have to come to terms with each other—so much alike are their inventions. Of the details of Mr. Edison's invention, if there are any, nothing is known beyond the fact stated in the "Scientific American," that it is a light produced from a spiral of incandescent platinum; while the reports in the American daily press show such an effervescent ignorance of the fundamental principles, both of electricity and of dynamics, that no reliancé whatever can be placed upon them.

Experience, then, has shown that a light by incandescence comes before us in a very questionable shape, and it is esentially a light which discourages the notion of its practical application. The question indeed may be very properly asked: How is it that light by incandescence has always proved such an utter failure? It has had a period of thirty-three years in which to develop; it has been divided into various lesser lights, numbering from two to two hundred; and it has arrested the attention and taxed the skill of the greatest electricians in the world. How is it that it is obliged to give way to light by the voltaic arc? The answer is at hand. The light by incandescence can only be obtained and divided by a great sacrifice of light and power. This is imperative from the fundamental principles of electrical science. The diminution according to the "square," and not according to simple proportion, applies to electricity just as it applies to light, heat, sound, gravitation, and other physical phenomena. Thus, if a circuit be divided into two branches whose resistances are equal, a current of half the strength passes through each branch producing at the point of resistance not half the light but only a quarter, because the effect follows the square of the current strength. If the current had been divided into three equal branches, in each branch only one-ninth part of the original light would be obtained, and so on, so that if an electric light of 1,000 candles were divided into ten equal lights the result would be ten lights of ten candles each instead of one of 1,000 candles. When this law is borne in mind, and when it is also remembered that to produce the electric light by incandescence at least one-half of the current is lost, it will easily be imagined what a wasteful light it is. Recent experiments prove this. It was recently stated, in reference to M. Werdermann's incandescent light, that he produced two lights of 320 candles each (total, 640 candles), with a prime mover of 2 horse-power, and this was considered a great result, as indeed it was for an incandescent light. But how this sinks into insignificance when compared with the results of lighting by the voltaic arc. A few days ago M. Rapieff, with two of his regulators and a small Gramme machine known as the M machine, and which M. Gramme says requires only 1½ horse-power, produced two lights which, when carefully measured by the photometer, were found to be each equal to 1,150 candles, or a total of 2,300 candles, while with one of M. Gramme's A machines, requiring 2½ horse-power, a light of 6,000 candles can be obtained from one of M. Rapieff's regulators. Some experiments detailed in M. Fontaine's book on "Electric Lighting" gave a similar result. M. Fontaine's experiments with an incandescent light show that under the most favorable circumstances with a Bunsen battery of forty-eight cells, eight inches high, the diminution of the subdivided light was so great that where he put five lights in one circuit he only obtained a total illuminating power of a quarter of a burner, with four lamps only three-quarters of a burner, with two lamps six and a half burners, and with one lamp fifty-four burners. These numbers give the following ratio: 1, 3, 8, 6, 216, thus showing how rapidly the light diminishes when divided. With the voltaic arc, however, and with the same battery he was able, by a Serrin lamp, to obtain a light of 105 burners.

It will be seen then, from what has been above stated, that the production and the divisibility of the light by incandescence is a very wasteful process, so wasteful, indeed, as to render its practical application impossible for general lighting. If, therefore, all Mr.

Edison has to announce to the world is that he has succeeded in dividing an incandescent light, and the announcement that such is so is made on authority, his discovery amounts to very little. Both the light and its divisibility were discovered long ago. It will easily be seen that it is not in that direction that any great practical results can be obtained. The voltaic arc supplies the only divisible light of any utility and economy, and it is in its development that any real progress must be looked for.

William Trant.

Complainant's Exhibit "Preface 2d Edition of Fontaine," March 13, 1880. S. M. H., Exr.

(Translation.)

ELECTRIC LIGHTING.

BY

HIPPOLYTE FONTAINE.

2d Edition—Paris, 1879.

PREFACE.

The first edition of this work was placed on sale in May, 1877, just two years ago. It has been translated into English and German, and all the impressions have been rapidly exhausted.

This success, very rare in respect to technical works, is particularly due to the important character of the sudject considered and to the practical information which we have succeeded in collecting together and in arranging in an orderly manner.

To-day, as in 1877, the electric light is the order of the day. A considerable number of inventors are occupied in improving its operation and manufacturers are begining to make a common use of it. Personally, we have made, in two years, several hundred installations and have collected a great number of notes concerning the labors of French and foreign electricians; thus enabling us to considerably increase the size of this new edition and to embrace in it a large number of unpublished data.

In a few words, the following is the present state of lighting by electricity.

The invention by Mr. Gramme has brought about the large introduction of the electric light into factories and machine shops; Messrs. Sautter and Lemonnier have brilliantly started it in navigation and the art of war; Mr. Breguet has made it specially known in laboratories and in England; Mr. Jaspar is occupied in promoting it in Belgium; Mr. Siemens in Prussia, Mr. Mercier in Austria, Mr. Konn in Russia, Mr. Dalman in Spain, etc.; and all at once the candle of Mr. Jablochkoff, aided by the Gramme machine, sheds its light in shops, in hotels and also upon the public ways.

Has this development appeared to increase forever as electricians hope, or are the existing installations going soon to disappear as gas companies affirm? To this it is easy to reply.

An industry is transient when its only foundation is fashion and when it does not meet a general want.

On the other hand, when it is of real service and is based upon truly economic principles, it grows.

Now, it is incontestible that when there is need of a very intense light at one point, as is the case in forts, to watch the enemy, in harbors to combat the destructive intent of torpedo boats, in lighthouses to guide mariners, the electric light is not only the most economical of all lights, but it is quite often the only light which is applicable.

It is equally certain that for a large dockyard like that of the outer port of Havre, or for a vast enclosure like that of the Hippodrome of Paris, where it is impossible to suspend lighting apparatus and place lamp posts on the track, the electric light is alone possible, the only light which can take the place of the absent sun.

First of all it can be affirmed that lighting by electricity has a field which is peculiar to it and where it does not even fear the competition of other systems.

This alone is sufficient to assure to it a great future, as also that it will not answer for many other applications.

For lighting private dwellings, gas offers the most desirable, the most convenient and the most economical means (solution). Electricity will indeed be able here and there to penetrate into some large drawing-rooms or into some costly mansions, but this will be an exception so rare that it is not necessary to take account of it.

For lighting public ways, gas also answers better. Still the large avenues and open squares are already able to avail of the Jablochkoff candles, and this in spite of the slight imperfections which are always encountered at the beginning of a new enterprise and which will soon disappear.

For large shops, large cafés, and in general for establishments which seek to attract custom by the fine appearance of the merchandise placed on sale or by the richness of their decorations, the electric light in part is a means for lighting (solution) which will force itself upon them in all the important cities.

For lighting factories, machine shops, forges, foundries and mills, the electric light presents itself with its advantages and its inconveniences in competition with gas, oil and petroleum. Most frequently gas and electricity are alone in competition.

Gas possesses, as a luminous agent, some remarkable properties; it produces a very uniform lighting resulting from its division into a large number of low power lights; its use is convenient and easy, because it is sufficient to open a cock for it to come to the burners; once lighted, it burns indefinitely without requiring attention; it can be lighted and extinguished as often as is necessary; its flame can be increased or diminished at will according to requirements and fade from the splendor of the most beautiful lamp to the glimmer of the most unpretending watch-light; finally, in almost all cities, it is always at the disposal of the consumer, night and day.

Its inconveniences are particularly in the disagreeable odor given out by the least leakage, in the yellow color of its flame which alters the tint of objects lighted, in the considerable heat which accompanies its combustion, which renders it unhealthy in poorly ventilated and crowded habitations; and especially in fires and explosions which it very frequently causes.

The electric light possesses advantages likewise very remarkable; it gives out a feeble heat, and takes from the surrounding air only a small part of its oxygen, which renders its use very healthful; it preserves the

tints of colors as they are in daylight, and permits the distinguishing of shades almost alike; it produces in factories a powerfully diffused (ambient) light which facilitates inspection, diminishes the chances of accidents and simplifies the labors of management; it can furnish foci of an extraordinary power to illuminate spaces far away from the place of their production, and to shed around it a splendid diffused light; it removes dangers of fire, and its cost is extremely small in proportion to its lighting power.

Its inconveniences, which are especially the consequence of its recent introduction (*mise en pratique*), and which the experience of some years will certainly partly overcome, can be summed up as follows: It loses much of its intensity when it is divided into small foci, which renders it difficult of application to small apartments; it is liable to extinction for a short time it is true, but with a disagreeable effect upon public ways; it necessitates the use of an engine; its production causes a noise often very fatiguing, and it requires some handling for renewing the carbons or candles.

If the workshops are made up of comparatively small rooms, if the ceilings are low, the machine tools large (élevé) and crowded together, gas is generally preferable to electricity. If the rooms are large, the ceilings sufficiently high, the tools well apart, electricity is generally preferable to gas. In each particular case conditions are to be taken into account which depend especially upon the price of gas in the locality, and upon the class of work to be done in the shops.

But in spite of the rivalry which will be established in certain cases between lighting by electricity and lighting by gas, the gas industry will never be arrested in its development by the electrical industry.

We have said at a meeting of the British Institute of Mechanical Engineers, and we cannot repeat it too often, that the electric light can neither injure gas nor oil lamps, nor candles, but on the contrary. It will not change, as certain financiers pretend, the question of lighting from foundation to roof, destroy that which exists, monopolize to itself alone all the industrial applications, domestic and public.

The electric light has its place fixed by a multitude of circumstances, but far from causing the end of other lights it will develop the use of them by demonstrating the advantages of a more intense and more perfect lighting.

The field for exploiting this new industry is immense, but it certainly does not represent the one hundredth part of the general lighting, and it may be predicted, without the least exaggeration, that general lighting will soon be increased.

Electricians may, therefore, pursue their researches, because their labors will receive, without any doubt, their just reward; on the other hand, the managers of the gas companies can remain tranquil, their rights are most certainly sheltered from a fall.

At least this is the humble opinion of the author.

Complainant's Exhibit Extracts from Chapter XIII., 2d Edition of Fontaine. S. M. H. Exr.

(Translation.)

ELECTRIC LIGHTING,

BY

HIPPOLYTE FONTAINE,

2d Edition, Paris, 1879.

CHAPTER XIII.

Lighting by Incandescence.

While, thanks to the efforts of M. M. Gramme and Jablochkoff, lighting by the voltaic arc has received considerable development, lighting by incandescence has likewise made rapid progress, which has even recently caused a great disturbance in the investments of the gas industry, although it has not yet been developed into anything practical. An American Journal, having stated that Mr. Edison was going to light an entire section of New York by electricity, a large number of the share-holders of gas companies, of the Old World as well as of the New World, hastened to sell their holdings, and threw the market for these excellent investments into a veritable panic.

To-day tranquility is restored, the statement of the journal is justly considered as a hoax, and shares have returned to their old value. But the market remains very sensitive, and we would not be surprised to soon see it again agitated by reports also devoid of foundation.

The truth is that the celebrated inventor of the phonograph has only re-edited a platinum wire lamp, which has already been experimented with, perfected and finally confessed to be unsuited to industrial use by several electricians of great merit.

We will rapidly examine the devices which have been proposed for producing the electric light by the use of a badly conducting body, raised, by the current, to a temperature near the point of fusion.

These devices can be divided into three classes: 1st, metallic spiral lamps; 2d, lamps with carbons held in clamps or sockets (*charbons encastres*); 3d, semi-incandescent lamps (*lamps a contact imparfait*). We will mention, particularly in the 1st class, the lamps of De Moleyns, Petrie, de Changy and Edison; in the 2d class the lamps of King, Lodyguine, Konn, Bouliguine and Fontaine, and in the 3d class the lamps of Varley, Reynier, Werdermann and Ducretal.

1st. Lamps with metallic spirals.

(Translator's note. Here follows a description of the lamps of de Moleyns, Petrie and de Changy.)

Edison's lamp. The experiments in lighting by incandescence of platinum continued after 1858, and several electricians attempted to render it practical; but none of them succeeded in advancing a single step in the matter. It was even believed that it had been abandoned forever, when this famous American note arose which attributed to Mr. Edison the honor of having solved completely the problem of the divisibility of the electric light by means of platinum spirals.

(Translator's note. Here follows a short account of Edison's French patent for a platinum spiral lamp.)

But all this does not constitute an invention susceptible of immediate applications and, still more so, to influence a market as important as that of gas investments.

2d. Lamps with carbons held in clamps or sockets.

Lighting with carbons held in clamps or sockets has been studied for a very long time; but its usual application has met with such great difficulties that to-day they are still to be considered as in a purely scientific stage, although to-day a certain number of devices exist which work pretty well

(Translator's note. Here follows a description of the carbon lamps of King, Konn, Bouliguine and Fontaine.)

3. Semi-incandescent lamps.

(Translator's note. Here follows a description of the lamps of Varley, Reynier and Werdermann.)

Of all the physicists who have occupied themselves with incandescence, M. de Changy has made the best spiral lamp, M. Konn the best lamp with carbons held in clamps or sockets, and M. Reynier the best semi-incandescent lamp. The last would, without doubt, arrive at a practical solution of the problem of lighting by small electrical foci, did it not present some difficulties almost insurmountable.

In the actual state of affairs, with the electrical generators in use and the lamps proposed for utilizing the electricity, we do not believe that lighting generally by electricity can be made to succeed.

Circumstances may present themselves where its application will be interesting and even useful, but to develop them, it is necessary to invent a gas engine of moderate price or thermo-electric batteries must become really practical. In the meantime we can recommend incandescent lamps, particularly that of M. Reynier, in laboratories and in factories which already have electrical lamps for powerful foci, and which can, without inconvenience, interpolate one or several semi-incandescent lamps in the circuit.

Con E L Co vs McKeesport Co } Deft's Exhibit No 2 W.O.J. S.E.

"Edison's Exhibit No 2" W.H.H. Notary public N.Y. Co.

NEW YORK HERALD, SUNDAY, DECEMBER 21, 1879.—QUADRUPLE SHEET—WITH SUPPLEMENT.

EDISON'S LIGHT.

The Great Inventor's Triumph in Electric Illumination.

A SCRAP OF PAPER.

It Makes a Light, Without Gas or Flame, Cheaper Than Oil.

TRANSFORMED IN THE FURNACE.

Complete Details of the Perfected Carbon Lamp.

FIFTEEN MONTHS OF TOIL.

Story of His Tireless Experiments with Lamps, Burners and Generators.

SUCCESS IN A COTTON THREAD.

The Wizard's Byplay, with Bodily Pain and Gold "Tailings."

HISTORY OF ELECTRIC LIGHTING.

The near approach of the first public exhibition of Edison's long looked for electric light, announced to take place on New Year's Eve at Menlo Park, on which occasion that place will be illuminated with the new light, has revived public interest in the great inventor's wo[illegible] throughout the civilized world scientists and people generally are anxiously awaiting the result. From the beginning of his experiments in electric lighting to the present time Mr. Edison has kept his laboratory guardedly closed, and no authoritative account (except that published in the HERALD some months ago relating to his first patent) of any of the important steps of his progress has been made public—a course of procedure the inventor found absolutely necessary for his own protection. The HERALD is now, however, enabled to present to its readers a full and accurate account of his work, from its inception to its completion.

A LIGHTED PAPER.

Edison's electric light, incredible as it may appear, is produced from a little piece of paper—a tiny strip of paper that a breath would blow away. Through this little strip of paper is passed an electric current, and the result is a bright, beautiful light, like the mellow sunset of an Italian autumn.

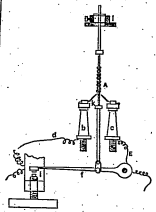
"But paper instantly burns, even under the trifling heat of a tallow candle!" exclaims the sceptic, "and how, then, can it withstand the fierce heat of an electric current?" Very true, but Edison makes the little piece of paper more infusible than platinum, more durable than granite. And this in-

such closing making a new passage for the electric current and cutting it off from the incandescent platinum. When the latter contracted, as it did the moment the heat was lessened, the lever returned to its normal position and allowed the electric current to again pass through the platinum. By this device the inventor hoped to be able to keep the incandescent platinum always below its melting point. The contrivance is described in his first patent as follows:—

THE FIRST LIGHT.

"Electric lights have been produced by a coil or strip of platinum or other metal that requires a high temperature to melt, the electric current rendering the same incandescent. In all such lights there is danger of the metal melting. My improvement is made for regulating the electric current automatically passing through such incandescent conductor, and preventing its temperature rising to the melting point, thus producing a reliable electric light."

FIGURE 1.



"Fig. 1 shows one form of the device. The incandescent metal is in the form of a double spiral A, the two ends terminating upon the posts b, c, to which the conductors d, E, are connected. A circuit closing lever, f, is introduced in the electric circuit, the points of contact being at 1, and there is a platina, or similar wire, k, connected with the lever, f, to the headpiece or other support, l. The current from a magneto machine is connected with the wires E and d. The current then flows from E to the post, c, thence around the platinum spiral to b, and is carried off by the wire, d. Now, when the rod, k, of platinum becomes heated to too great intensity its expansion closes the lever, f, and the current then passes from E, through f, and not through the spiral at all. In this way the lever cuts off the current every time the heat becomes too intense."

Numerous other devices of a similar character were tried and for a while they all worked satisfactorily, but the inventor finally discovered that the constant expansion of the platinum rod k and its pressure upon the lever f bent it so that it became unreliable and it was, therefore, abandoned.

THE SECOND PLATINUM LAMP.

The next regulator was in the form of a diaphragm, which cut off the electric current from the platinum every time the diaphragm was pressed outward beyond a fixed limit by the heated air. The regulation thus produced was so rapid that the eye could not perceive any diminution in the strength of the current. But this also was inadequate in many respects. The next important modification in the light was the substitution for the platinum spiral of finely divided platinum incorporated with non-conducting material. When the electric current was passed through the combination the platinum particles became incandescent and the non-conducting material incorporated with them became luminous and increased the brilliancy. One advantage by this form not previously attained was that a very weak electric current produced a good light.

THE BOBBIN LAMP.

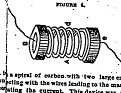
After this followed a device of [illegible] light-giving surface, the platinum being wound in the form of a small bobbin, first having been coated with a non-conducting coating that was not injured by the heat. With this arrangement a new form of

heated by the passage of the electric current through it. E is a thin piece of zircon that receives the heat rays thrown off by the reflector, C, which heat rays bring up the zircon, E, to vivid incandescence, making it give out a light much more brilliant than the light of the platinum spiral, C. With this form Mr. Edison tried numerous experiments, and from time to time made many alterations and improvements, but eventually the apparatus was placed in the category of non-successes.

ANOTHER SPIRAL.

Realizing from the first the necessity of the light giving substance offering much resistance to the passage of the electric current—a necessity in extensive subdivision of the light—the inventor throughout his experiments kept a close watch for substances and forms that gave suitable resistances. In figure 4 is shown a form of lamp disconnected from the regulating apparatus, which largely embodied the above requirement and for a time gave good results.

FIGURE 4.

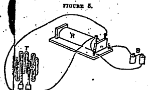


A is a spiral of carbon with two large ends, B, c, connecting with the wires leading to the machine for generating the current. This device was tried for several weeks, but did not, as a whole, give satisfaction.

EVERY MAN HIS OWN ELECTRIC LIGHTER.

Branching off from the line of investigation he had been previously following Mr. Edison at this time began experimenting with a view to having the light produced locally—i. e., arranging for each householder to become his own manufacturer of light, thus dispensing with mains and central stations. The apparatus which he used for this purpose is shown in figure 5:—

FIGURE 5.



R is an induction coil such as are used by peripatetic showmen at fairs and other places when they give electric shocks to inquiring sightseers at so much per shock. It is operated by two cells of battery B, and wires lead from it to the glass tubing, T, from which the air has previously been extracted, the passage of the electric current through the [illegible] giving out a light. This plan is analogous to what is known as the Geisler tube arrangement, the difference being in the form of the tube and the extreme smallness of the bore and also in the degree of vacuum produced. Mr. Edison succeeded by this arrangement in obtaining a light of several candle power with a moderately powerful induction coil. The light, however, was not the one sought after so persistently by the inventor, and so it took its place in that part of his laboratory occupied by inventions not in use.

OSMIUM-IRIDIUM.

Once more Mr. Edison made a departure. He moulded powdered metallic oxides in the form of sticks and subjected them to a very high temperature. In this connection he obtained very fine results from the native alloy of osmium-iridium called iridosmine, which alloy he used in the form of a powder enclosed in a tube of zircon. The electric current passing through the same brought it to a beautiful incandescence.

CARBON AND PLATINUM.

The inventor's next important move was the adaption of carbon in connection with platinum as the substances to be made incandescent. He caused a slender rod of carbon to rest upon another of platinum, the inferiority of contact between the two at their point of meeting producing a resistance to the passage of the electric current and causing the carbon to become highly incandescent, while the platinum attained only a dull red heat. The carbon rod was kept pressing upon the platinum by a [illegible]

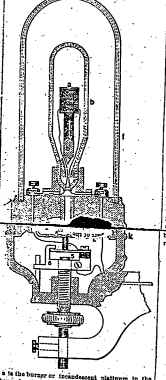
magnesia and subjected to the vacuum process described, a combination takes place between the metal and the oxide, giving the former remarkable properties. With a spiral having a radiating surface of 3-16 of an inch light equal to that given by forty standard candles may be obtained, whereas the same spiral, not coated by my process, would melt before giving a light of four candles. The effect of the oxide of magnesia is to harden the wire to a surprising extent and render it more refractory. A spiral made of this wire is elastic and springy when at high incandescence. I have found that chemically pure iron and nickel drawn in wires and subjected to the vacuum process may be made to give a light equalling that of platinum in the open air. Carbon sticks also may be freed from air in this manner and be brought to a temperature where the carbon becomes pasty and on cooling it is homogeneous and hard.

THE FIRST PLATINUM VACUUM LAMP.

About this time another truth dawned upon the inventor—namely, that economy in the production of light from incandescence demanded that the incandescent substance should offer a very great resistance to the passage of the electric current. Concerning this the inventor writes:—"It is essential to reverse the present practice of having lamps of but one or two ohms (electrical units) resistance and construct lamps which, when giving their proper light, shall have at least two hundred ohms resistance."

The lamp, as it stood at this stage of the inventor's progress, is shown in figure 6.

FIGURE 6.



a is the burner or incandescent platinum in the shape of a bobbin supported within the vacuum tube, b, by a rod, b', of the same material as the bobbin. The vacuum tube, b, is sustained by the case, E, and around said tube, b, is a glass globe, l. Within the case, k, is a flexible metallic [illegible] chamber, L, that opens into the glass case, [illegible] the air, when expanded by heat, can pass [illegible] flexible diaphragm, x, and parts connected therewith. When the current circulating around the

twain, but not before it had emitted a light of several gas jets. Eagerly the inventor hastened to examine under the microscope this curious filament, apparently so delicate, but in reality much more infusible than platinum, so long considered one of the most infusible of metals. The microscope showed the surface of the filament to be highly polished and its parts interwoven with each other.

THE PAPER LIGHT.

It was also noticed that the filament had obtained a remarkable degree of hardness compared with its fragile character before it was subjected to the action of the current. Night and day, with scarcely rest enough to eat a hearty meal or catch a brief repose, the inventor kept up his experiments, and from carbonizing pieces of thread he went to splinters of wood, straw, paper and many other substances never before used for that purpose. The results of his experiments showed that the substance best adapted for carbonization and the giving out of incandescent light, was paper preferably thick like card board, but giving good results even when very thin. The beautiful character of the illumination and the steadiness, reliability and non-fusibility of the carbon filament were not the only elements incident to the new discovery that brought joy to the heart of Edison. There was a further element—not the less necessary because of its being hidden—the element of a proper and uniform resistance to the passage of the electric current.

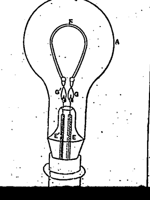
The inventor's efforts to obtain this element had been by far the most laborious of any in the history of his work from the time he undertook the task, and without it absolute success to electric incandescent illumination could not be predicated, even though all the other necessary properties were present in the fullest degree.

Passing over the scores of experiments made since the discovery that the carbon framework of a little piece of paper or thread was the best substance possible for incandescent lighting, we come to consider the way in which the same is prepared at the present time in the laboratory.

MAKING THE PAPER CARBON.

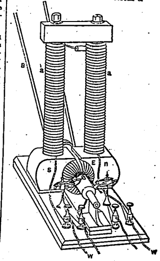
With a suitable punch there is cut from a piece of "Bristol" cardboard a strip of the same in the form of a miniature horseshoe, about two inches in length and one-eighth of an inch in width. A number of these strips are laid flatwise in a wrought iron mould about the size of the hand and separated from each other by tissue paper. The mould is then covered and placed in an oven, where it is gradually raised to a temperature of about six hundred degrees Fahrenheit. This allows the volatile portions of the paper to pass away. The mould is then placed in a furnace and heated almost to a white heat, and then removed and allowed to cool gradually. On opening the mould the charred remains of the little horseshoe cardboard are found. It must be taken out with the greatest care, else it will fall to pieces. After being removed from the mould it is placed in a little globe and attached to the wires leading to the generating machine. The globe is then connected with an air pump, and the latter is at once set to work extracting the air. After the air has been extracted the globe is sealed, and the lamp is ready for use. Figure 7 shows the lamp complete:—

THE PERFECTED LAMP—FIGURE 7.



in a general way, how his machine operates. Figure 8 shows the generating or Faradic machine, as Edison terms it, in honor of Faraday, complete.

THE GENERATING MACHINE—FIGURE 8.



a a are two upright iron columns, three feet high and eight inches in diameter, wound with coarse wire and resting upon the base, n and s, which form its magnetic poles. This part of the apparatus is called the field of force magnet. Fixed on an axle, so as to freely revolve between the poles n and s, is a cylindrical armature of wood, e, wound parallel to its axes with fine iron wire. When this cylinder or armature is made to revolve rapidly between the magnetic poles n and s, by means of the belt B, driven by an engine (not shown in the cut), there is generated in the wire surrounding the armature e strong currents of electricity, which are carried off by the wires, W W, to the electric lamps.

A DOMESTIC MOTOR.

By constructing the machine in the form shown in figure 9 there is obtained an electric motor capable of performing light work, such as running sewing machines and pumping water. It forms part of the inventor's system and may be used either with or without the electric light. To run an ordinary sewing machine it requires only as much electricity as is necessary to give out one electric light of the strength of a common gas jet. To put it in operation on a sewing machine the housewife has merely to attach it by a little belt at A with the wheel of the sewing machine, and turn on the electricity by touching a little knob conveniently attached. The cost is the same as if she was burning one electric light.

THE ELECTROMETER.

The apparatus for measuring the amount of electricity used by each householder is a simple contrivance consisting of an electrolytic cell and a small coil of wire, appropriately arranged in a box, the latter being of about half the size of an ordinary gas meter, and like a gas meter it can be placed in any part of the house. The measurement is obtained by the deposit of copper particles on a little plate in the electrolytic cell, such deposit being caused by the electric current passing through the cell. At the end of any period, say one month, the plate is taken by the inspector to the central office, where the copper deposit is weighed and the amount of electricity consumed determined by a simple calculation.

In addition to the various parts of the system above described, there are a number of other details, not so important to be sure as those of which sketches have been given, but nevertheless essential to make up the complete plan of economical electrical illumination. A description of these latter will not be attempted, as a proper understanding of them involves a technical knowledge of the laws of electricity. The entire system embraces an amount of work so extensive that one naturally wonders how a [illegible] world scientists and people generally are anxiously awaiting the result. From the beginning of his experiments in electric lighting to the present time Mr. Edison has kept his laboratory guardedly closed, and no authoritative account (except that published in the HERALD some months ago relating to his first patent) of any of the important steps of his progress has been made public—a course of procedure the inventor found absolutely necessary for his own protection. The HERALD is now, however, enabled to present to its readers a full and accurate account of his work, from its inception to its completion.

A LIGHTED PAPER.

Edison's electric light, incredible as it may appear, is produced from a little piece of paper—a tiny strip of paper that a breath would blow away. Through this little strip of paper is passed an electric current, and the result is a bright, beautiful light, like the mellow sunset of an Italian autumn.

"But paper instantly burns, even under the trifling heat of a tallow candle!" exclaims the sceptic, "and how, then, can it withstand the fierce heat of an electric current?" Very true, but Edison makes the little piece of paper more infusible than platinum, more durable than granite. And this involves no complicated process. The paper is merely baked in an oven until all its elements have passed away except its carbon framework. The latter is then placed in a glass globe connected with the wires leading to the electricity producing machine, and the air exhausted from the globe. Then the apparatus is ready to give out a light that produces no deleterious gases, no smoke, no offensive odors—a light without flame, without danger, requiring no matches to ignite, giving out but little heat, vitiating no air, and free from all flickering; a light that is a little globe of sunshine, a veritable Aladdin's lamp. And this light, the inventor claims, can be produced cheaper than that from the cheapest oil. Were it not for the phonograph, the quadruplex telegraph, the telephone and the various other remarkable productions of the great inventor the world might well hesitate to accept his assurance that such a beneficent result had been obtained, but, as it is, his past achievements in science are sufficient guarantee that his claims are not without foundation, even though for months past the press of Europe and America has teemed with dissertations and expositions from learned scientists ridiculing Edison and showing that it was impossible for him to achieve that which he has undertaken.

HIS FIRST ATTENTION TO ELECTRIC LIGHTING.

When Edison began his experiments in September, 1878, he had just returned from the inspiring scenery of the Rocky Mountains, where he had been enjoying a little recreation after several months of hard labor. He was ripe for fields and enterprises new. A visit to a Connecticut factory where an electric light was used concentrated his thoughts on the subject of lighting by electricity, and he determined to attack the problem. Previous to this time, although he had roamed broadcast over the domain of electricity, wresting from it, as is well known, many of its hidden secrets, Edison had scarcely thought of the subtle fluid in connection with practical illumination. Now, however, he bent all his energies on the subject, and was soon deep in the bewildering intricacies of subdivision, magneto currents, resistance laws and the various other branches going to make up a system of lighting by electricity. The task before the young inventor was divisible into two parts.

First—The producing of a pure, steady and reliable light from electricity; and

Second—Producing it so cheaply that it could compete with gas for general illumination.

HE CHOOSES INCANDESCENCE.

Of the two systems before him—viz., voltaic arc and the incandescence system, Edison chose the latter as his field of operations. Prominent among the difficulties incident to incandescent lighting, it will be remembered, was the liability of the platinum (when that metal was used) to melt under the intense heat of the electric current, and the liability of the carbon, when that was employed, to gradually become dissipated under the combined action of gases and the electric current.

THE PLATINUM LIGHT.

As between platinum and carbon as the substance to be made incandescent, Edison took up platinum and devoted first his attention to the obtaining of some device to prevent the platinum from melting under the intense heat of the electric current. An ingenious and simple contrivance met the requirement. He arranged a small lever, about three inches long, so that the expansion of the platinum (caused by the heat) beyond a certain degree would close it, every time the heat becomes too intense."

Numerous other devices of a similar character were tried and for a while they all worked satisfactorily, but the inventor finally discovered that the constant expansion of the platinum rod k and its pressure upon the lever f bent it so that it became unreliable and it was, therefore, abandoned.

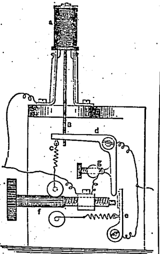
THE SECOND PLATINUM LAMP.

The next regulator was in the form of a diaphragm, which cut off the electric current from the platinum every time the diaphragm was pressed outward beyond a fixed limit by the heated air. The regulation thus produced was so rapid that the eye could not perceive any diminution in the strength of the current. But this also was inadequate in many respects. The next important modification in the light was the substitution for the platinum spiral of finely divided platinum incorporated with non-conducting material. When the electric current was passed through the combination the platinum particles became incandescent and the non-conducting material incorporated with them became luminous and increased the brilliancy. One advantage by this form not previously attained was that a very weak electric current produced a good light.

THE BOBBIN LAMP.

After this followed a device for obtaining a light-giving surface, the platinum being wound in the form of a small bobbin, first having been coated with a non-conducting coating that was not injured by the heat. With this arrangement a new form of regulator was used. The lamp at this stage is shown in figure 2.

FIGURE 2.



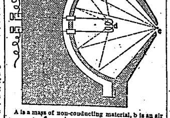
A is the incandescent bobbin; between the coils of which is a coating of magnesia. The top of the bobbin has a metallic cap connected to the lever, d. A spring, C, draws the rod, B, downward with considerable pressure, and this, of course, places pressure on the top of the bobbin, thus keeping the wire in contact with the upper end of the coil. The bobbin, A, expands as a whole by the heat and draws the rod, B, upward. This brings the lever attached upward and allows the lever, E, to come in contact with the screw, f, permitting the current to find a passage other than that afforded by the incandescent material.

The inventor next followed with a new regulator and a meter for measuring the amount of electricity used; also an automatic switch connecting the regulator with the line leading to the machine for generating the electric current.

THE REFLECTOR LAMP.

The next was a unique idea, making the platinum give the light as it were by proxy. By means of a reflector he concentrated the heat rays of the platinum upon a piece of zircon, causing the latter to become luminous. Figure 3 shows the apparatus:—

FIGURE 3.



A is a mass of non-conducting material, b is an air space, c is a polished reflector of copper coated with gold, d is a platinum-iridium spiral, which becomes what is known as the Geisler tube arrangement, the difference being in the form of the tube and the extreme smallness of the bore and also in the degree of vacuum produced. Mr. Edison succeeded by this arrangement in obtaining a light of several candle power with a moderately powerful induction coil. The light, however, was not the one sought after so persistently by the inventor, and so it took its place in that part of his laboratory occupied by inventions not in use.

OSMIUM-IRIDIUM.

Once more Mr. Edison made a departure. He moulded powdered metallic oxides in the form of sticks and subjected them to a very high temperature. In this connection he obtained very fine results from the native alloy of osmium-iridium called iridosmine, which alloy he used in the form of a powder enclosed in a tube of zircon. The electric current passing through the same brought it to a beautiful incandescence.

CARBON AND PLATINUM.

The inventor's next important move was the adoption of carbon in connection with platinum as the substances to be made incandescent. He caused a slender rod of carbon to rest upon another of platinum, the inferiority of contact between the two at the point of meeting producing a resistance to the passage of the electric current and causing the carbon to become highly incandescent, while the platinum attained only a dull red heat. The carbon rod was kept pressing upon the platinum by a weight ingeniously arranged. A dozen or more forms of this lamp were made; but, after all, the inventor was obliged to return to platinum as the substance most suitable, all things considered, for being made incandescent. For two months he worked at platinum day and night, only to find that platinum, as he had been using it, was entirely worthless for incandescent lighting. To many experimenters this would have proved a discouragement perhaps fatal, but it had the effect only of increasing Edison's determination.

THE CRACKS IN PLATINUM.

After scores of new experiments he arrived at the true causes of the defects and hastened to apply the remedy. "I have found, he writes, that when wires or sheets of platinum, iridium or other metallic conductors of electricity that fuse at a high temperature are exposed to a high temperature near their melting point in air for several hours by passing a current of electricity through them and then are allowed to cool, the metal is found to be ruptured, and under the microscope there are revealed myriads of cracks in various directions, many of which reach nearly to the centre of the wire. I have also discovered that, contrary to the received notion, platinum or platinum and iridium alloy loses weight when exposed to the heat of a candle; that even heated air causes it to lose weight; that the loss is so great a hydrogen flame is tinged green. After a time the metal falls to pieces; hence wire or sheets of platinum or platinum and iridium alloy as now known in commerce are useless for giving light by incandescence—

First—Because the loss of weight makes it expensive and unreliable and causes the burner to be rapidly destroyed.

Second—Because its electrical resistance changes by loss in weight, and its light-giving power for the total surface is greatly reduced by the cracks or ruptures.

The melting point also is determined by the weakest spot of the metal.

PLATINUM IN VACUO.

By my invention or discovery I am able to prevent the deterioration of the platinum or its alloys by taking off or intercepting the atmospheric action. A spiral wire or other forms of platinum is placed in a glass tube or bulb, with the wire near its ends passing through and sealed in the glass, and the air is exhausted from the glass. The platinum wires of the spiral are then connected to a magneto-electric machine or battery, the current of which can be controlled by the addition of resistance. Sufficient current is allowed to pass through the wire to bring it to about 150 degrees Fahrenheit. It is then allowed to remain at this temperature for ten or fifteen minutes. While thus heated both the air and gases contained in the metal are expelled by the heat or drawn by the vacuum action.

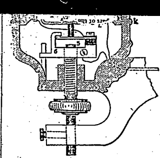
[illegible] this air or the gases are passing out of the metal the mercury pump is kept continually working.

At the expiration of about fifteen minutes the current passing through the metal is augmented so that the temperature will be about 300 deg. Fahrenheit, and this is allowed to remain at this temperature for another ten or fifteen minutes.

The mercury pump is to be worked continuously and the temperature of the spiral raised at intervals of ten or fifteen minutes until it attains vivid incandescence and the glass is contracted where it has passed to the pump and melted together.

BRILLIANT RESULTS.

Here the wire is now in a perfect vacuum and in a state heretofore unknown, for it may have its temperature raised to a most dazzling incandescence, emitting a light of twenty-five standard candles, whereas before treatment the same radiating surface gave a light of only about three standard candles. The wire, as after being thus free from gases are found to be a polish exceeding that of silver and obtainable by no other means. No cracks can be seen even after the spiral has been raised suddenly to incandescence many times by the current, and the most delicate balance fails to show any loss of weight in the wire even after it is burning for many hours continuously. I have further discovered that if an alloy of platinum and iridium is coated with the oxide of



a is the burner or incandescent platinum in the shape of a bobbin supported within the vacuum tube, b, by a rod, b', of the same material as the bobbin. The vacuum tube, b, is sustained by the case, k, and around said tube, b, is a glass globe, l. Within the case, k, is a flexible metallic air-tight chamber, L, that opens into the glass case, l, so that the air, when expanded by heat, can pass into the flexible chamber and give motion to the flexible diaphragm, x, and parts connected therewith. When the current circulating around the bobbin, a, becomes too intense and heats the latter too highly the air within the glass case, l, is expanded and bulges downward by the diaphragm, x, and the pin thereon pressing upon the spring, 5, and separating said spring from the block, 6, breaks the circuit to the burner. The temperature within the globe, l, lowers immediately and the parts return to their normal position, closing the circuit through the burner to 5 and 6. This opening and closing of the circuit is but momentary, and, therefore, the uniform brilliancy of the light is not affected and there is no danger of the burner becoming too highly heated.

PERFECTING THE MACHINERY.

The lamp, after these latter improvements, was in quite a satisfactory condition, and the inventor contemplated with much gratification the near conclusion of his labors. One by one he had overcome the many difficulties that lay in his path. He had brought up platinum as a substance for illumination from a state of comparative worthlessness to one well nigh perfection. He had succeeded, by a curious combination and improvement in air pumps, in obtaining a vacuum of nearly one millionth of an atmosphere, and he had perfected a generator or electricity producing machine (for all the time he had been working at lamps he was also experimenting in magneto-electric machines), that gave out some ninety per cent in electricity of the energy it received from the driving engine. In a word, all the serious obstacles toward the success of incandescent electric lighting, he believed, had melted away, and there remained but a comparatively few minor details to be arranged before his laboratory was to be thrown open for public inspection and the light given to the world for better or for worse.

A GREAT DISCOVERY.

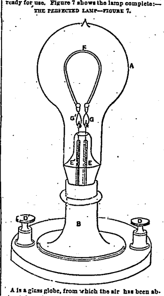
There occurred, however, at this juncture a discovery that materially changed the system and gave a rapid stride toward the perfect electric lamp. Sitting one night in his laboratory reflecting on some of the unfinished details, Edison began abstractedly rolling between his fingers a piece of compressed lampblack mixed with tar for use in his telephone. For several minutes his thoughts continued far away, his fingers in the meantime mechanically rolling out the little piece of tarred lampblack until it had become a slender filament. Happening to glance at it the idea occurred to him that it might give good result as a burner if made incandescent. A few minutes later the experiment was tried, and, to the inventor's gratification, satisfactory, although not surprising results were obtained. Further experiments were made, with altered forms and composition of the substance, each experiment demonstrating that at last the inventor was upon the right track.

A COTTON THREAD.

A spool of cotton thread lay on the table in the laboratory. The inventor cut off a small piece, put it in a groove between two clamps of iron and placed the latter in the furnace. The satisfactory light obtained from the tarred lampblack had convinced him that filaments of carbon of a texture not previously used in electric lighting were the hidden agents to make a thorough success of incandescent lighting, and it was with this view that he sought to test the carbon remains of a cotton thread. At the expiration of an hour he removed the iron mould containing the thread from the furnace and took out the delicate carbon framework of the thread—all that was left of it after its fiery ordeal. This slender filament he placed in a globe and connected it with the wires leading to the machine generating the electric current. Then he extracted the air from the globe and turned on the electricity.

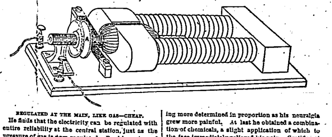
Presto! a beautiful light greeted his eyes. He turns on more current expecting the fragile filament instantly to fuse; but no, the only change is a more brilliant light. He turns on more current, and still more, but the delicate thread remains entire. Then, with characteristic impetuosity and wondering and marvelling at the strength of the little filament, he turns on the full power of his machine and eagerly watches the consequence. For a minute or more the tender thread seems to struggle with the intense heat passing through it—heat that would melt the diamond itself—then at last it succumbs and all is darkness. The powerful current had broken it in been extracted the globe is sealed, and the lamp is ready for use. Figure 7 shows the lamp complete:—

THE PERFECTED LAMP—FIGURE 7.



A is a glass globe, from which the air has been abstracted, resting on a stand, B. F is the little carbon filament connected by fine platinum wires, G G', to the wires, E E', leading to the screw posts, D D', and thence to the generating machine. The current, entering at D, passes up the wire E to the platinum clamp, G; thence through the carbon filament F to G', down the wire E' to the screw post D'; thence to the generating machine. It will be noticed, by reference to the complete lamp in figure 7, that it has no complex regulating apparatus, such as characterized the inventor's earlier labors. All the work he did in regulators was practically wasted, for he has lately realized that they were not at all necessary—no more so than a fifth wheel is to a coach.

THE DOMESTIC MOTOR—FIGURE 9.



REGULATED AT THE MAIN, LIKE GAS—CHEAP.

He finds that the electricity can be regulated with entire reliability at the central station, just as the pressure of gas is now regulated. By his system of connecting the wires the extinguishment of certain of the burners affects the others no more than the extinguishment of the same number of gas burners affects those drawing the supply from the same mains. The simplicity of the completed lamp seems certainly to have arrived at the highest point, and Edison asserts that it is scarcely possible to simplify it more. The entire cost of constructing them is not more than twenty-five cents.

EASY METAMORPHOSIS.

The lamp shown in figure 7 is a table lamp. For chandeliers it would consist of only the vacuum globe and the carbon filament attached to the chandelier and connected to the wires leading to the generating machine in a central station, perhaps a half mile away, the wires being run through the gas pipes, so that in reality the only change necessary to turn a gas jet into an electric lamp is to run the wires through the gas pipe, take off the jet and screw the electric lamp in the latter's place. Although the plans have been fully consummated for general illumination the outline of the probable system to be adopted is the locating of a central station in large cities in such a manner that each station will supply an area of about one-third of a mile. In each station there will be, it is contemplated, one or two engines of immense power, which will drive several generating machines, each generating machine supplying about fifty lamps.

THE GENERATING MACHINE.

Mr. Edison's first experiments in machines for generating the electric current did not meet with success. His primal apparatus was in the form of a large tuning fork, constructed in such a way that its ends vibrated with great rapidity before the poles of a large magnet. These vibrations could be produced with comparatively little power. Several weeks of practice proved, however, that the machine was not practical, and it was laid aside. Then followed a number of other forms, leading up gradually to the one at present used. Bearing in mind the principle common to all magneto-electric machines—viz., that the current is produced by the rotation of magnets near each other—it will not be difficult to understand, the sewing machine, and [illegible] touching a little knob conveniently attached. The cost is the same as if she was burning one electric light.

THE ELECTROMETER.

The apparatus for measuring the amount of electricity used by each householder is a simple contrivance consisting of an electrolytic cell and a small coil of wire, appropriately arranged in a box, the latter being of about half the size of an ordinary gas meter, and like a gas meter it can be placed in any part of the house. The measurement is obtained by the deposit of copper particles on a little plate in the electrolytic cell, such deposit being caused by the electric current passing through the cell. At the end of any period, say one month, the plate is taken by the inspector to the central office, where the copper deposit is weighed and the amount of electricity consumed determined by a simple calculation.

In addition to the various parts of the system above described, there are a number of other details, not so important to be sure as those of which sketches have been given, but nevertheless essential to make up the complete plan of economical electrical illumination. A description of these latter will not be attempted, as a proper understanding of them involves a technical knowledge of the laws of electricity. The entire system embraces an amount of work so extensive that one naturally wonders how a single man in such a brief space of time as fifteen months could possibly have planned and perfected it all. And surprise becomes greater when it is considered that during this period Edison found time to make other inventions. A sextuplex telegraph, or apparatus for sending six messages on one telegraph wire in opposite directions simultaneously, saw life during the progress of the electric light, patents for the same having only just been issued. Several new and important improvements in his chalk telephone, by which the efficiency of that invention is greatly increased, also attest his industry and versatility of genius.

POLYFORM.

But perhaps the latter quality is more strikingly exhibited in his polyform or preparation by which he is enabled to bid defiance to sick headaches, neuralgia and other nervous diseases, and to make himself largely independent of physicians in times of ailment. The polyform grew out of necessity. Being considerably afflicted with neuralgia and obtaining no relief from his physician, Edison set about becoming his own doctor. His chemical laboratory, one of the most complete in the United States, furnished him an ample field from which to draw. Experiment followed experiment, the inventor becoming more determined in proportion as his neuralgia grew more painful. At last he obtained a combination of chemicals, a slight application of which to the face immediately relieved his pain. Gratified at his success, but hardly yet convinced, he tried the preparation on others similarly afflicted and with equally satisfactory results.

"IN CORPORE VILI."

About this time there happened to stroll into the laboratory one day a dilapidated tramp on his periodic begging expedition from place to place. Now, this tramp was a particularly unfortunate one, his poverty being hardly more distressing than his physical ailments. One of his legs was swelled with rheumatism, neuralgia coursed along his face and a dozen or more sores and bruises made him a veritable Job. Happening to meet him Edison saw in him a most excellent subject for further polyform experiments. A hearty meal and a little change readily procured the tramp's consent, and soon the inventor was subjecting his new acquaintance to all sorts of chemical experiments. For more than a week the tramp found food and lodging in Menlo Park, giving in return a few hours of his time every night to be experimented upon. By the time his engagement was over his rheumatism and neuralgia had disappeared, and his sores were well nigh healed. The news of the tramp's good fortune soon spread, and now it is no uncommon thing for neighbors to come to the inventor's laboratory from miles around to request a little polyform—a request which the inventor always good naturedly complies with.

GOLD "TAILINGS."

The very, very latest enterprise of the indefatigable scientist is a scheme for obtaining gold out of "tailings," or the sand thrown away by miners as having been worked out. Rumor has it that Edison has succeeded in obtaining a chemical preparation which will take from $200 to $300 per ton out of "tailings" from which the present processes can obtain nothing. The matter, however, is as yet a profound laboratory secret.

ELECTRIC LIGHTING BEFORE EDISON.

Among its other properties electricity has that of developing heat. A substance through which an electric current is made to flow becomes heated to a degree proportioned first to the strength of the current, and second, to the size and character of the

Complainant's Exhibit "Dr. Morton's Sanitary Engineer Letter." January 20, 1890. S. M. H., Exr.

[*Sanitary Engineer, January 1, 1880.*]

To the Editor of The Sanitary Engineer:

Having a sincere respect for Mr. Edison as an enthusiastic and ingenious investigator, I am sorry to see his name used by writers who evidently are quite ignorant of the subjects about which they treat in a way that will inseparably connect it with discreditable (because false) claims, evidently made in the interest of financial speculators.

No one can more thoroughly appreciate than I do the originality of conception, the indefatigable patience and immense labor which have been involved in the series of experiments of which a sketch has been given in the "New York Herald" of Sunday the 21st; but when I see the conclusion of these, which every one acquainted with the subject will recognize as a conspicuous failure, trumpeted as a wonderful success, I have only left before me the two alternative conclusions that the writer of such matter must either be very ignorant, and the victim of deceit, or a conscious accomplice in what is nothing less than a fraud upon the public.

Such writing as this, in fact, has the melancholy result of placing Mr. Edison and his electric light in the same category with Mr. Keeley and his "water motor," Mr. Payne and his "electric engine," Mr. Garey and his "magnetic motor," and others of the same class.

Against this I protest in behalf of true science and for the sake of Mr. Edison himself, who has done and is doing too much really good work to have his record defaced and his name discredited in the interests of any stock company or individual financiers.

Henry Morton.

Stevens Institute of Technology,
December 22d, 1879.

P. S.—When I say that the achievements described by the Herald of Sunday, the 21st, constitute "a conspicuous failure," I do not of course mean that Mr. Edison has not now, as he had a year ago, a lot of electric lamps running at Menlo Park; but that his year's work, starting out with the most confident assertion of an accomplished success, only awaiting granting of patents to be made public, has ended in landing him in an old method repeatedly tried and abandoned by others, and which this description furnishes no reason to believe has received any important improvement in Mr. Edison's hands.

Complainant's Exhibit "Dr. Morton's Times Interview of December 28, 1879." January 20, 1890. S. M. H., Exr.

[*New York Times, December 28th, 1879.*]

A SCIENTIFIC VIEW OF IT.

PROFESSOR HENRY MORTON NOT SANGUINE ABOUT EDISON'S SUCCESS.

Professor Henry Morton, the President of the Stevens Institute of Technology, who is well known for his researches in physics, and whose experiments were a source of unfeigned pleasure and astonishment to Prof. Tyndall, recently sent a communication to the Sanitary Engineer protesting against the trumpeting of the result of Edison's experiments in electric lighting as "a wonderful success," when "every one acquainted with the subject" will recognize it as a "conspicuous failure." To this was added the statement that Edison "has done and is doing too much really good work to have his record defaced and his name discredited in the interests of any stock company or individual financiers." Edison, to whose attention this letter was called, was reported in a newspaper yesterday morning as inviting Prof. Morton or any other electrician to visit the Menlo Park laboratory and see the light in practical operation. In conversation with a "Times" reporter yesterday Prof. Morton said that for several reasons he did not think he would accept Mr. Edison's kind invitation. "What is needed to be learned," said the Professor, "is the durability of these new lamps of Mr. Edison's and the actual economy in the conversion of power into light by his arrangement. For example, according to the statement in the Sun, Mr. Edison places his present lamps and machines as yielding him what is equivalent to 10 gas burners for every horse power. Now, my own experience with the best dynamo-electric machines, such as those of Siemens, Weston, Brush and Maxim, using the ordinary carbon poles, show that we may obtain a light of from 1,200 to 1,600 candles per horse power. Assuming a gas burner to be equal to from 12 to 16 candles, this would be about 100 burners per horse power. As compared, therefore, with the electric light obtained between carbon poles Mr. Edison gets only 10 per cent., showing, therefore, precisely that enormous loss in the division of the light which has been alluded to before as one of the standing difficulties in the way of the practical application of such a system as Mr. Edison is working upon. This is taking simply his apparently rough estimate. For any definite and certain conclusions prolonged and careful experiments entirely under the control of the investigator are absolutely necessary."

As regards the durability of Prof. Edison's new lamps Prof. Morton was not at all sanguine. "Lamps," said he, "in all essential respects identical with these described by Mr. Edison have been in constant experimental use for several years past with one invariable result, namely, that while the carbon would operate successfully for periods varying from a few hours to several days, it has been found utterly impossible to render them reliably permanent. It is, therefore, in my estimation, here also necessary that experiments of some length, likewise under the entire control of the investigator, should be made in order that a decisive conclusion may be reached. With reference to the confident assertions of success which reach me from various quarters I must fall back upon my experience of a little over a year ago. Every one remembers how at that time Mr. Edison read some remarks of mine by the light of his then brilliantly glowing electric light, and pointed to it as a shining refutation. In turning over some old letters a few days since I came across one from a friend of mine who is a scientific man of high standing, and was at that time on very intimate terms with Mr. Edison. This letter is dated October , 1878, and in it I am assured that Mr. Edison's lamp is a perfect success, capable of replacing a gas-burner with perfect ease, and that when I see it I shall, no doubt, be charmed with its sim-

plicity and efficiency. When I reflect that this previous complete success has been since abandoned by Mr. Edison, I feel that a little caution is needed in accepting the enthusiastic conclusions of his friends, even when they are illuminated by the shining electric lamps which occasion them."

"Can you tell me, Professor," asked the reporter, "what are some of the chief difficulties in the way of the success of Mr. Edison's light?"

"Well," Prof. Morton replied, "the first difficulty of all is the production of a lamp which shall be thoroughly reliable, and neither complicated or expensive. All attempts up to the present lamp in this direction are acknowledged to be failures, and, as I have pointed out, there does not seem to be any novelty such as would authorize us to hope for a better success in the present one. The next difficulty is in the economical production of small lights by electricity. This is what is commonly meant by the phrase, 'Dividing the electric light.' Up to the present time, and including Mr. Edison's latest experiments, it appears that this involves an immense loss of efficiency. Next comes the difficulty of distributing on any large scale the immense electric currents which would be needed, and to provide for their equal action at different points under varying conditions of the number of lights used. In reference to this, as far as I judge from the reports, Mr. Edison has been running not over 50 lights in all, while his 80 horse-power engine ought to supply 800 lights. The small number actually in use does not, therefore, develop this problem in any practical way."

"The question of measuring the current," added the Professor, as the reporter turned to leave, "the loss involved from the necessity of running the machinery without a moment's intermission during the entire time that any light is needed—in other words, the absence of any storing capacity in electricity—and various other matters of detail, while less important than the three principal difficulties which I have given you are, nevertheless, very serious difficulties in the direction of a successful practical application of electricity for general illumination."

Complainant's Exhibit "Sawyer's Sun Letter of December 22, 1879." January 22, 1890. S. M. H., Exr.

[*New York Sun, December 22d, 1879.*]

ELECTRICIAN SAWYER'S CHALLENGE TO ELECTRICIAN EDISON.

If a party possesses an interest in something that he considers valuable, he is not very likely to part with it, especially if it be something in the line of electric lighting, where what may nominally be $1 may really be $1,000. Therefore, when Mr. Edison sells out all his interest in his electric light there is a reasonable chance for a suspicion that he considers his invention worth very little.

Mr. Edison's reputation before the public is founded upon the newspaper publications about: 1. The quadruplex telegraph; 2. The telephone; 3. The phonograph.

As to the quadruple telegraph, I may say that it was an adaptation of the French and German systems. When Mr. Edison took hold of the 4-plex there was already known five systems of 2-plex, three of 4-plex, and three of 6-plex and 8-plex.

The 4-plex of Edison was a failure. A modest young gentleman, assistant electrician of the Western Union Telegraph Company, whom I have not seen for several years (Mr. Gerritt Smith), made it a success, and some day he will get the credit for this invention; for he, and not Edison, is the genius in this case.

As to the telephone, Mr. Edison is not the inventor. Andrew Graham Bell is the inventor of the telephone.

As to the phonograph, which really made Mr. Edison's reputation, it is of no earthly value, and the manufacture by Bergman has practically been dropped. The real inventor of the phonograph will never be known, in all probability, for I understand that Mr. Edison anticipates a Western man but three days in priority of invention.

Now, all that remains for Mr. Edison is electric light. He is going over the same ground that Bouliguine, Lodygreine, Kosleff, Konn, Starr King, myself and others have traversed—first, iron; second, platinum; third, carbon in different shapes. And Edison has failed, in my opinion. To show that I mean what I say, I deny every one of his allegations made at the Saratoga Convention of the American Society for the Advancement of Science, and, specifically, I challenge him:

FIRST. To maintain a vacuum in his lamps.

SECOND. To run his carbonized paper lamp three hours (In practice, in a perfect vacuum, it will last twenty minutes).

THIRD. To consolidate platinum by heating electrically in the Sprengel vacuum, as he claims.

FOURTH. To prove that his dynamo-electric machine develops not ninety, but even forty-five per cent. of the feet pounds applied to it.

FIFTH. To show that he can obtain a light of twenty-five candles from platinum with less than three-horse power.

SIXTH. To show that platinum or iridium will not disintegrate in twenty hours' actual running.

SEVENTH. To prove that with his carbonized-paper lamp he can obtain two lights of ten candles each per horse power.

EIGHTH. To show that the effect of the oxide of magnesium is to harden his wire, and make it more refractory.

And I further allege that all Mr. Edison's statements are erroneous, and I offer $100 as a prize for him to prove each of the above eight allegations. Let him run one of his lamps three hours and the public will be satisfied that I am correct.

W. E. SAWYER.

78 Walker Street, New York, Dec. 21.

Complainant's Exhibit "Sawyer's Herald Letter of Dec. 24, 1879," Jan'y 22, 1890. S. M. H., Exr.

[*New York Herald, December 24th, 1879.*]

SAWYER ON EDISON AND THE HERALD.

NEW YORK, Dec. 23, 1879.

TO THE EDITOR OF THE HERALD:

Your interesting editorial of to-day advises me not to try conclusions with the Wizard of Menlo Park. I am quite anxious to try them, and not remarkably easy to alarm, and shall not at present accept your advice, however well intended. The "Herald" is at perfect liberty to advocate Mr. Edison's claims and I am at perfect liberty to advocate my own. If you care to settle the question of priority of invention upon the horseshoe lamp as between Mr. Edison and myself you may inspect one of those lamps which broke down at No. 94 Walker street about a year ago, and, after many experiments, was so far condemned that Mr. Mann and I concluded we would not waste enough money on it to pay for a patent. This lamp is at present just exactly as it was removed from the bracket, hermetically sealed in a glass globe filled with nitrogen gas and in just exactly the same condition as it was in a year ago. To avoid any question I placed said abandoned institution in the hands of Messrs. Arnoux & Hochhausen, No. 2 Howard street, yesterday (Monday) morning at nine o'clock. So far as I am concerned the Wizard is welcome to patent it. I fail to see what difference it can make to the "Herald" whether Mr. Edison or somebody else invents the successful electric lamp. Mr. Edison over a year ago began this controversy by an attack upon me. He has received one in return, and evidently does not like it. I expect he will have something to say himself in return for that, and I am prepared to meet him half way on any point whatever that he may bring up. There is no occasion for personalties on the part of the "Herald" that I can understand, or for threats.

Next week I shall show my system of electric household illumination in this city in practical operation, and if I do not prove it superior to anything else I am much mistaken, and if I do show to those interested that it is superior, all the personalties in the "Herald" or by Mr. Edison will not prevent capital putting it where it will do the most good.

W. E. SAWYER.

Complainant's Exhibit "Sawyer's World Letter of Dec. 24, 1879," Jany. 22, 1890. S. M. H., Exr.

[*New York World, December 24th, 1879.*]

EDISON'S ELECTRIC LIGHT.

Mr. Sawyer Questions the Novelty and the Practical Value of the Discovery.

To the Editor of the World:

Sir:—My attack upon Mr. Edison in the Monday's Sun was provoked by his constant appropriations of the credit due to others, not that he never accomplished anything himself, for we know that he has done a great deal in the advancement of science. It does not follow because he has made some correct deductions that all he says must be correct; nor because he has made many failures that he is not, as I believe him to be, a mechanical genius. What I claim is that he is not what he professes to be, an electrician.

The credit of electric lighting does not belong to any one man. Its present degree of perfection is due to the labors of a hundred experimentors as brilliant as Mr. Edison, and probably much more so than I am. My own position in the matter is that which follows three years of study, and in that time I have taken out a dozen or fifteen patents on electric lighting alone, so that when Mr. Edison made his startling announcement fifteen months ago he must have known from the printed records of the Patent Office, with which he never fails to provide himself, that what he claimed was not his own. His system of distribution, his means of regulating the current in his lamp, &c., had been fully covered by my patents. The very platinum lamp that was so much noised about had been made a year before Edison's announcement of it, shown to everybody and cast aside as worthless by Mr. H. S. Maxim of this city. It was cast aside because platinum shortly disintegrates, and because it takes three horse power to produce the light of a first-class gas jet from it with the best machines known. Mr. Edison afterwards secured a patent upon it because Mr. Maxim had not considered it worth patenting himself.

I would not dare to allege that Mr. Edison's scheme was not a genuine one; nor that it has been used to humbug the people in subscribing to worthless interests; nor that the gas men are at the bottom of the whole scheme, and mean to show, by the failure of a gentleman popularly supposed to be supernatural that no one else can ever accomplish anything to injure the gas interests. I simply point out the facts that the Sawyer-Man lamp and various improvements upon it as fast as made have been successfully exhibited for more than a year, and that the brilliant lamps of other inventors are notoriously in practical use in our streets to-day, while all we have heard from Menlo Park is that Mr. Edison is a great and eccentric genius who divides his time between eating herrings, wearing old hats, rolling tar abstractedly in his fingers, going without his dinner, and finally founding his great achievement upon, as has always really been the case, cotton thread and paper.

This does not prove, however, that Mr. Edison may not some day do something. I only allege that up to this time he has done absolutely nothing that is new or valuable in electric lighting, and I am prepared to stake my reputation as an electrician upon this statement.

The immediate cause of my challenge to Mr. Edison was my information that friends of his saw in my laboratory months ago the identical horseshoe lamp that is set up as his latest and grandest achievement, and my belief that he could not have failed to know that it was my invention. I object decidedly to his claiming my invention as his own, especially when it seems clear that the object of the announcement was to raise money. Over a year ago I experimented with the horseshoe lamp and found it a failure, even with the carbon much harder and more tenacious than paper carbon. Some dozen of these lamps were constructed.

The average life of the horseshoe was an hour. One of these lamps, with the horseshoe complete (except at the point where rupture occurred when the lamp broke down), is still hermetically sealed in its glass tube, and still charged with nitrogen just as it was taken from the bracket in January last. I handed it to Messrs. Arnoux & Hochhausen, 2 Howard street, yesterday morning, at nine o'clock, in order that no loophole may be left for prestidigitation at Menlo Park. If this does not settle the question of priority, I don't know what will settle it. A further fact about the horseshoe lamp is that it is so complete a failure that we decided nearly a year ago it would be wasting money to spend $35 for a patent upon it. The time has passed for any more electric light sensations. The only thing that can revive the subject is proof-practical demonstration, with the lamps kept out of the hands of those whose interest it may be to manipulate them. I accept the situation; I am more than anxious to try conclusions with Mr. Edison; I reiterate my challenge to him, and I don't propose that Mr. Edison shall escape the issue he has drawn upon himself.

He says he proposes to exhibit his light at Menlo Park next week. Next week I shall exhibit my light in New York in practical household use. The public can then judge for itself whether my system is a failure, and whether Mr. Edison has not been either himself deceived or persistently deceiving the community. Until then I shall have no "more last words" on the subject.

Respectfully yours,

W. E. Sawyer.

New York, December 23d.

Complainant's Exhibit "Sawyer's Tribune Interview of Jan. 2, 1880," Jan. 22, 1890. S. M. H., Exr.

[*New York Tribune, January 2, 1880.*]

MR. SAWYER SKEPTICAL.

His Views in Regard to the Practicability of the New Edison Lamp.

Mr. W. E. Sawyer, of No. 78 Walker street, in this city, who has made long and careful researches into the problem of the electric lamp, was found at his office yesterday busily engaged in the perfection of a new invention designed for illumination. He is very much interested in the new claims of Mr. Edison, and was quite willing to express his opinion in regard thereto. He said:

"The public has received from Menlo Park the following positive assertions: (1) That Mr. Edison's new lamp consists of a horseshoe of carbon about two and one-half inches long, clamped in platinum holders and hermetically sealed in a glass globe from which the air has been exhausted. (2) That the horseshoe, consisting of carbonized bristol-board, is so tough and flexible that it can be twisted nearly half way round without breaking. (3) That the horseshoe of carbon, no oxygen being present in the globe, will last an ordinary lifetime; that it has already been run over 100 hours without suffering deterioration. (4) That the light from each lamp is about equal to an ordinary gas jet, or say 10 or 12 candles. (5) That no dynamo machine known can generate sufficient electricity to destroy one of Mr. Edison's horseshoes. (6) That the chief point of advantage in the new lamp is its high resistance—140 ohms. There are other statements, but the foregoing cover the ground pretty thoroughly. Having during the past three years made the most complete series of experiments respecting electric lighting by incandescence that have probably ever been made, I am enabled to speak positively about many points that to those unfamiliar or only partially familiar with the subject may seem uncertain, or else correct when entirely wrong."

"First, then," asked the reporter, "what is your idea about the use of platinum for conducting wires?"

"The use of platinum as a holder for the incandescent carbon conductor," replied Mr. Sawyer, "is fatal to the durability of a lamp. Carbon only of larger section than the incandescent carbon can be employed, for the reason that at a white heat the carbon combines with the platinum to form the platinic carbide, and disintegration takes place with great rapidity. The same is true of any metal. I have welded carbon pencils in all shapes, and the best way to establish the connection of the incandescent carbon with its holders is to weld the two together. This I have done by first clamping the horseshoe in carbon holders, then inverting the lamp and immersing horseshoe and holders in any hydro-carbon, preferably pure olive oil, finally turning on a torrent of electricity so that the horseshoe is made intensely incandescent. With great violence the oil is decomposed, the hydrogen escaping, and the carbon being deposited, most rapidly at the points of contact of the horseshoe and its holders. The weld is so perfect that the horseshoe will break anywhere else rather than at the joints."

"Mr. Edison's paper carbon is very much longer than yours, Mr. Sawyer?"

"Yes; and when a length of incandescent conductor of one-half inch is reached the current can no longer be economically used because to increase the size is to increase the radiating surface, and the short carbon can be made to give all the light desired, viz., from 25 to 250 candles."

"What do you think of the kind of carbon which Mr. Edison employs?"

"The denser, harder and more homogeneous the carbon the tougher it is, and the more durable the lamp, for the reason that the whole action of the current (that very action which produces light, an intense vibration of the atoms or molecules of the carbon, amounting to several hundred trillions of vibrations per second), is to disrupt and disintegrate the carbon. The carbon formed by the process discovered in my experiments is the only one thus far that offers hope of permanency—a fine pencil of carbon being immersed in olive oil or any hydro-carbon gas or liquid, and electrically heated as in the process of welding before described, whereby it is built up with carbon so hard and homogeneous that it may be polished like jet. As we descend from this we get less durable material, the order of durability being: (*a*) Carbon. deposited by electric action; (*b*) The hardest retort carbon; (*c*) The best artificial carbon; (*d*) Hard coke; (*e*) Dense charcoal (charcoal impregnated with syrup and the syrup carbonized); (*f*) Willow, paper and other fine charcoal; (*g*) Ordinary charcoal; (*h*) Graphite. Mr. Edison's carbon belongs to the class *e* or *f*, and as carbon in all its forms is extremely brittle, his statement that his paper carbon is so tough and flexible that it can be twisted half way round, &c., without breaking, is open to criticism. The best carbons of the charcoal order we have produced by impregnating with syrup the finest French willow charcoal, used by artists, and carbonizing the same, repeating this process a sufficient number of times. This is substantially the process of Peyret and of Gaudoin. In pencils of $\frac{1}{8}$ inch diameter and $\frac{1}{2}$ inch length, with perfect carbon connections, and in an atmosphere of pure nitrogen, not even the $\frac{1}{100,000,000}$ of oxygen being present, these carbons will last as follows, under the action of the electric current: (*a*) At a red heat, giving a light of perhaps $\frac{1}{2}$ of a candle, 100 to 200 hours; (*b*) At between a red and a white heat, giving a light of 1 or 2 candles, 20 hours; (*c*) At a white heat, light 4 candles, 5 hours; (*d*) At true carbon incandescence, when the pencil has the limpid appearance of the sun, and gives a light of 25 or 30 to 250 candles, 20 to 5 minutes, or even less than 1 minute, disintegration then occurring very rapidly but no consumption taking place. The smaller the section of the pencil, the shorter its life

The larger the section the more current required. The longer the pencil the more current required."

"Do you think that the horseshoe lamps are liable to be injured by an accidental and sudden increase in the strength of the current?"

"When a carbon is in a high state of incandescence" replied Mr. Sawyer, "double the current invariably ruptures or disintegrates the carbon. If Mr. Edison will only bring the current necessary for ten of his lamps suddenly into one of them he will be surprised at the beautiful manner in which it will disappear. Experience has demonstrated that within reasonable bounds the less the resistance of an electrical circuit which includes the resistance of the wires of the machine, and that of the lamps outside of it, the less the power required for effective work. The arrangement of Mr. Edison's lamps in multiple circuit so as to lessen the external resistance where a large number of lamps are to be run is hazardous. In running 2,500 lamps by a single generator the mean will be found in a square of fifty in a series and fifty in multiple. This would make the external resistance of Mr. Edison's circuit 140 O., requiring an intensity of current that would give violent shocks to those who might by accident touch the conductors, and a most costly insulation of the main wires. To place less lamps in series and more in multiple is as hazardous as to go the other way, inasmuch as it would increase the chances of a short circuit extinguishing lamps in other series. No lamp can be practical unless of low resistance."

Complainant's Exhibit "Sawyer's 'Sun' Letter of Jan. 5, 1880." Jany. 22, 1890. S. M. H., Exr.

[*New York Sun, Monday, January 5, 1880.*]

MR. EDISON CHALLENGED BY MR. SAWYER.

To the Editor of the "Sun," Sir: Notwithstanding the assertion that one of Mr. Edison's electric lamps has been running 240 hours, I still assert, and am prepared to back up my assertion, that Mr. Edison can not run one of his lamps up to the light of a single gas jet (to be more definite, let us call it twelve candle power) for more than three hours. To be still more definite, I offer to Mr. Edison, at 226 West Fifty-fourth street, in this city, an opportunity to prove what he says. From the private residence in that street wires are run a circuit of 1,000 feet. Mr. Edison shall have every facility; he shall use my wires; he shall have any dynamo-machine or other generator of electricity he may prefer; and all I ask is that the power of his light shall be measured by a photo-meter; that, once in place, it shall not be interfered with; and that a committee of gentlemen, preferably nominated by the editors of the New York press, shall be present and certify to the facts of the test.

Furthermore, I will place one of my lamps side by side with Mr. Edison's; it shall be run at the power of twenty-five candles; it shall outlast the entire forty lamps at Menlo Park, run at the power of twenty-five candles; my lamp to stand as it is put up, and Mr. Edison to put up a fresh lamp as fast as the preceding lamp shall have burned out.

I am anxious for this test; and if Mr. Edison has really run one of his horseshoe lamps 240 hours he will not refuse to accept my offer, for he will be treated with the utmost courtesy, and shall have everything his own way.

I adhere in every particular to my original challenge to Mr. Edison.

W. E. SAWYER.

78 Walker street, New York, Jan. 4.

Complainant's Exhibit "Sawyer's Herald Letter of Jan. 5, 1880." Jany. 22, 1890. S. M. H., Exr.

[*New York Herald, January 5, 1880.*]

No. 78 Walker Street,
New York, January 4, 1880.

To the Editor of the "Herald":

Notwithstanding the assertion that one of Mr. Edison's electric lamps has been running for 240 hours I still assert, and am prepared to back up my assertion, that Mr. Edison cannot run one of his lamps up to the light of a single gas jet (to be more definite, let us call it twelve-candle power) for more than three hours. To be still more definite I offer to Mr. Edison at No. 226 West Fifty-fourth street, in this city, an opportunity to prove what he says.

From the private residence in that street wires are run a circuit of 1,000 feet. Mr. Edison shall have every facility; he shall use my wires; he shall have my dynamo machine or other generator of electricity he may prefer, and all I ask is that the power of his light shall be measured by a photometer; that once in place it shall not be interfered with; and that a committee of gentlemen, preferably nominated by the editors of the New York press, shall be present and certify to the facts of the test.

Furthermore, I will place one of my lamps side by side with Mr. Edison's; it shall run at a power of 25 candles; it shall outlast the entire forty lamps at Menlo Park run at the power of 25 candles; my lamp to stand as it is put up and Mr. Edison to put up a fresh lamp as fast as the preceding lamp shall have burned out. I am anxious for this test, and if Mr. Edison has really run one of his horseshoe lamps 240 hours he will not refuse to accept my offer, for he will be treated with the utmost courtesy and shall have everything his own way. I adhere in every particular to my original challenge to Mr. Edison.

Respectfully,
W. E. Sawyer.

Complainant's Exhibit "Sawyer's Herald Letter of Jan. 6, 1880." Jany. 22, 1890. S. M. H., Exr.

[*New York Herald, January 6, 1880.*]

Mr. Sawyer's Exhibitorium.

To the Editor of the Herald:

Your remarks this morning were both interesting and to the point. A great newspaper, as the Herald undoubtedly is, should be impartial. I don't know much about the newspaper business, but I know that much. In all the time that I have been working at this problem of electric lighting, I have been working simply and solely with a view to a genuine scientific success. I have made no money out of it. Instead of selling out I have increased my original interest by $19,000; have bought my own stock from those to whom I made a gift of it at 50 per cent. of its par value. I think I know enough about this business not to make a very great mistake, and not risking my reputation by any wild challenges.

The Herald is in error in implying that this is my residence, and that in consequence this is a kind of a family matter. I hunted New York over to find some one who would permit me to use his house for a public exhibition. As may be imagined, it was not an easy thing to do. Allow me to correct. My residence is No. 261 West Forty-second street; my office is No. 78 Walker street, my shop is No. 141 Elm street, the exhibitorium is No. 226 West Fifty-fourth street.

W. E. Sawyer.

Complainant's Exhibit "Du Moncel La Lumiere Electrique Article No. 2." Feb'y 28, 1890. S. M. H., Exr.

La Lumiere Electrique, Tome II.,

No. 1, 1er Janvier, 1880., pp. 12-13.

(Translation.)

SOME REFLECTIONS IN REGARD TO THE NEW LAMP OF MR. EDISON.

It is not without astonishment that I hear of the fresh excitement produced in the financial markets by the incredible puff which I read in the "New York Herald," on the subject of Mr. Edison's new lamp, which is taxed as a *great discovery*, and regarded as a *great triumph* of Mr. Edison. In truth, one must have lost all recollection of the *American hoaxes*, to accept such claims, for besides that this system shows absolutely nothing new, as regards its principle, the article seems inspired by a thought which may be easily divined by referring to a communication from Mr. Goddard, secretary of the Edison Light Company, who announces that the object of the association is, at present, only to give Mr. Edison the means of pursuing his experiments; that, if these experiments are successful, the company will *realize great profits*, otherwise *it will be dissolved;* this communication ends with this somewhat naive avowal that the project of the *sorcerer of Menlo Park* is magnificent, but that *it is far from its conception to its realization.*

What astonishes me is, that after the successive alarms which have come to us on three different occasions from Menlo Park, people should still allow themselves to be caught by the accounts of Mr. Edison's reporters, and, above all, that he should be regarded as

an oracle. Mr. Edison, it is true, is a very ingenious, very productive inventor, but nothing more, and he even appears not to be acquainted with the subtleties of the electrical science, nor with the discoveries made long before him. Already, as to his telephone, it has been demonstrated that the principle on which it is based, did not belong to him[1], and if good search were made it might likewise be proven that the *idea* of the phonograph, if not its realization, also does not belong to him. His first lamp was but a modification of that of Monsieur de Changy, contrived in 1858; and that which is announced to us to-day seems to be nothing but a modification of those of Messrs. King, Lodyguine, Bouliguine and Sawyer-Man, etc. It does not even offer the ingenious arrangement of Mr. Konn's lamp, which prevents the extinction of the light in case of the rupture of the incandescent carbon.

In 1875 much noise had also been made on the subject of the lamp with incandescent carbon which, introduced in France by Mr. Kosloff, was tested for some time at Mr. True's, lamp maker, of Paris, and it was claimed, at that time, that an *Alliance* machine could illuminate 15 lamps of this kind; but in fact I have never been able to see more than two operating at a time. It was in consequence of these discomfitures that Messrs. Reynier and Werdermann had the idea of adding the effects of combustion and of the voltaic arc to those of incandescence, and, as has been seen, they obtained much better results. To-day Mr. Edison takes us backwards, and it is the Lodyguine lamp which he resuscitates under a different form.

Instead of small needles of retort carbon fixed at their extremities in cubes of the same material, it is a kind of bundle of sheets of charcoal of carbonized Bristol cardboard, separated by a metallic tissue and bent into a horseshoe form so as to be set in communi-

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[1] I discovered this principle in the year 1856 and have since studied it on four different occasions, in 1864, 1872, 1875 and 1876.

cation with the rheophores of the circuit by platinum wires rendered, no doubt, less fusible by a process which has already been talked of.* The receiver in which this system is enclosed is besides void of air like that originally used by Monsieur Lodyguine. It is possible that the arrangement of which we have just spoken may be better than those which have preceded it, but assuredly it does not constitute an invention of the standard spoken of in the American papers. Even the idea of the intercalation of metallic bodies in the interior of the carbonized mass, in order to make it a better conductor and more solid, is not new, for it had already been realized by Messrs. Jablochkoff and Ikelmer.

It is besides difficult to admit that this horseshoe of charcoal, so slender and so delicate, does not deteriorate by a prolonged incandescence; for besides the calorific action which tends to disaggregate the carbonaceous particles, a mechanical action of the current is produced which tends to carry them off and deposit them on the sides of the receiver, as is noticed in the tubes of Geissler.

On the other hand, this metallic tissue which separates the carbonaceous layers of the incandescent horseshoe, might well be impaired by the heat in the long run, though it were constituted of platinum wires almost infusible. In this, experience will alone be able to decide, and that is why it is prudent to remain in expectancy, notwithstanding the announcements of 50 or 60 lights being lit in this manner by a single machine.

As to the greater brigtness of the light with carbons of vegetable origin, a property which, according to the American papers, constituted especially the superiority of the system of Mr. Edison, I must say again that this is a phenomenon that has been observed long ago.

In the five editions of my notice on the apparatus of

* This bundle is composed of strips of carbonized Bristol card-board, two inches in length by one-eighth of an inch in width, which have been cut and placed into an iron mold heated to 500°.

Ruhmkorff I mention it; thus, on p. 33 of the first edition, published in 1855, we read as follows:*

* * * * * *

"If the reophores terminate in pieces of *wood-charcoal*, the spark passes at a distance as with the metals, only the two points of contact with the charcoals *are very much brighter.* If this spark is shortened, it soon takes on, at the negative pole, a *particular and radiating brilliancy which may be compared to that of a point of electric light* issuing from a strong voltaic battery; it is, moreover, perfectly white.

* * * * * *

"The retort carbon presents the same effects as the wood-charcoal, *but they are less bright, it is the utmost when the light produced is radiating.*

"With cork made conducting by immersing it in sulphuric acid, or sheepskin moistened with acidulated water, the *phenomenon is still much more developed and much more intense than with carbon.* So luminous a point is then obtained that it is difficult to look at it. At the same time the cork and the sheepskin are carbonized and burn."

At the time when I presented my luminous tube for the illumination of the obscure portions of the human body to the Academy, jointly with Monsieur Fonssagrives, I had thought of utilizing this illuminating property of the carbonized vegetable substances, and here is what I say about it in the 4th edition of my notice on the apparatus of Ruhmkorff, published in 1859 (see p. 344):

"The problem may be solved in two ways, either by means of the passage of the induced current through a small recurved tube and void of air, or by means of the spark exchanged between *two small sheets of quenched carbon* separated by a plate of hardened caoutchouc and introduced into the interior of a tube after having been set in communication with *two rather fine metallic wires.* With a little care, one can in this way make a

* See in the 3d edition p. 48, and in the 5th p. 111.

kind of small lamps, 3 millimetres in diameter, which can have enough brilliancy to illumine a restricted space in a very bright manner."

I have, however, given the preference to the first means, because of the heat evolved in the second arrangement.

It is also advisable to make the most express reservations concerning the dynamo-electric machine of the same inventor, which offers nothing quite new, and on the subject of which theories have been put forth which, if they were true, would modify the so well-established laws of Ohm and of Joule, theories which, besides, disagree with all the experiments made with the other machines. I prefer to believe that Mr. Edison has not accounted for the maximum effects which he describes, and which have, besides, been contested by two well-known electricians of his own country.

May I be permitted, in closing, to protest against the off-handedness with which the Americans treat the European inventions; it is hardly to be believed. It seems, according to them, that the electrical science arose yesterday, and that it is America which has discovered it! I might cite many examples of this to which Mr. Prescott's name is not foreign, but I prefer to stop here.

I think that the preceding is sufficient for the public to be on its guard against the pompous announcements which come to us from the new world.

TH. DU MONCEL.

Complainant's Exhibit, Engineering Article of January 2, 1880. S. M. H., Ex'r.

Extract from an article in "Engineering," of January 2, 1880, Vol. XXIX., p. 13, entitled,

"THE BRUSH ELECTRIC LIGHT."

More than a year has passed by since the scientific world was startled and a panic struck into the breasts of gas shareholders, by the cablegram announcing that Mr. Edison had solved the problem of the divisibility of the electric light and that he would speedily supply such lights into all households at a cost far below that of gas. Enthusiasts in his rare inventive faculty were disposed to believe this announcement; but more prudent critics threw doubts on its reliability; and as time went on without bringing with it the promised lamp the public at large began to be sceptical of the alleged discovery; and all the sanguine confidence of Mr. Edison himself, and the highly colored reports of Yankee correspondents, could not shake the opinion which gradually gained ground that he had discounted success. The communication made by him during the summer to the American Association for the Advancement of Science on the tempering of metals in vacuo, however, showed that he was still fighting manfully with difficulties occasioned by the lack of a metal sufficiently refractory to withstand the high temperature which it is necessary for his metal burner or "electro-pyre," if we may be permitted to coin a word, to acquire without fusing and few who know the strength of his genius and the resources at his command will doubt that if success can possibly be attained in the line which he has chosen, he of all other living inventors is the likeliest to reach it. The great advantage of the incandescent mode over the arc is that it yields a softer and steadier light, in fact, a light as nearly perfect as any light need be. But this advantage is more than counterbalanced by the extra cost of production. Mr. Edison, it is understood, has at last approached very near to, if indeed he has not achieved, a complete success. The latest information from Menlo Park is to the effect that after vainly ransacking the world in quest of platinum-iridium in quantity, he has discovered in a sheet of stout drawing paper all that he requires. Not the bowels of the earth nor the metallurgist, but the desk at his hand and the paper-maker is to be his friend after all. Mr. Edison takes a strip of the cartridge-paper, cuts out of it a small slip in the pattern of a horseshoe, bakes it in an iron mould, puts it inside a glass globe, from which he exhausts the air to one-millionth of an atmosphere by means of a Sprengel pump with a McLeod gauge, and having provided the requisite wires for the transmission of the electric current, he sends the electricity through the charred paper, and behold! it glows with a soft and brilliant light. The lamp may be hung up anywhere and the light will take care of itself. It is to cost only a shilling (twenty-five cents), and Mr. Edison intended to celebrate the advent of the new year, and his own victory over the powers of darkness, by illuminating the village of Menlo Park on New Year's Eve with 800 lamps. Sixty lights have been burning for some weeks in Mr. Edison's laboratory, and the "Times" correspondent reports that he has seen them and believes them to be a complete substitute for gas. Each individual lamp gives a light of 16 candles, equal to one first-class gas-jet; the resistance of the carbon and connections being 100 ohms. Light is turned on or off with the same ease as gas is, while the current can be transmitted through a wire as small as No. 36. A central regulator is used to maintain an even current from the generator to the lamps, while the amount of electricity used by each consumer is measured by meters. Mr. Edison is said to find that the best generators are those of five to seven horse-power, each horse-power being able to feed eight lamps. As regards the cost of light he avers that three pounds of coal as fuel will supply eight to ten lamps for an hour. The light itself is said to be bright and clear but mel-

low and steady, more agreeable to the eye than gaslight, and available for at least every purpose to which gaslight is applied. We can of course understand how a slip of carbonized paper can be made to produce an excellent electric light in this way; but until further experience has shown that the slip will endure without disintegrating it would be premature to congratulate Mr. Edison on his undoubted success.

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Complainant's Exhibit "Engineering" Article of January 9, 1880. S. M. H. Exr.

Editorial preface from an article in "Engineering," January 9th, 1880, p. 37. Under the heading:

"Edison Electric Light."

"Almost the whole civilized world appears to be waiting with feverish anxiety for full details and confirmation of Prof. Edison's latest discovery in electric lighting. If he had indeed arrived at the solution claimed, and has produced a domestic light free from the disadvantages hitherto attendant on electric illumination and those which are inseparable from gas; a light at the same time cheap in production, entirely under control, capable of regulation and requiring no special management; it is certain that for the first time since the problem of electric lighting has been studied that gas has found a dangerous rival. Pending precise and technical information on this all-important subject, we are compelled to content ourselves with the more published notices of American journals. We believe that the following description, taken from the "New York Herald," is the most complete that has yet appeared." Here follows a copy of the "New York Herald" article of December 21st, 1879.

the fact that probably one-half the effort put forth in Sunday-school work is wasted, and some of it worse than wasted.

Too much attention to questions of dogmatic belief, and too little to questions of conduct; too much bondage to the teaching of the Bible and related subjects as an end, and too little devotion to the production of Christian character; too much superficial and revivalistic work, and too little broad philanthropic endeavor; too much frivolity and perfunctory lesson-hearing, and too little of the affectionate, life-long attachment of god-parent and god-child between teacher and pupil; too much system and too little freedom and common-sense; too much memory and too little sympathy—these criticisms can justly be made against much of our Sunday-school work in the hundredth year after Robert Raikes of Gloucester.

The time will come and the leader will come. He will teach us as Jesus taught, that the Book, and the day of rest, and the creed symbol, are all subordinate to the welfare of the human spirit, and that practical endeavor, if it will achieve its best result, must disentangle itself from theoretic idealism, and from bondage to dogmatism, tradition, and convention.

EDISON'S ELECTRIC LIGHT.

BY FRANCIS R. UPTON (MR. EDISON'S MATHEMATICIAN).

Editor Scribner's Monthly.

Dear Sir: I have read the paper by Mr. Francis Upton, and it is the first correct and authoritative account of my invention of the Electric Light.

Menlo Park, N. J. Yours Truly, Thomas A. Edison.

The crowning discovery of Mr. Edison—the electric light for domestic use—is at last a scientific and practical success. A mistaken idea has been afloat that this new light was intended to be a rival of the sun, rather than what it really is,—a rival of gas. The contrivances of the new lamp are so absurdly simple as to seem almost an anti-climax to the laborious process of investigation by which they were reached. A small glass globe from which the air has been exhausted, two platinum wires, a bit of charred paper—and we have the lamp. The generator of the electricity is simpler than a gas-generator, and the wires for its distribution are more manageable than are gas mains and pipes. The light is equal to gas in brightness and whiter in color; it is inclosed and, consequently, perfectly steady; it gives off no appreciable heat; it consumes no oxygen; it yields up no noxious gases, and, finally, it costs less than gas. The difficulty of subdivision Mr. Edison has also overcome: in his method of illumination a number of separate lights can now be supplied from the same wire, and each one, being independent, can be lighted or extinguished without affecting those near it.

In order to a clear comprehension of the electric light, a few words upon the general subject are necessary. All illuminants are produced by the incandescence or white heat of matter. This matter may either be in a finely-divided state—the particles widely separated—as in the flame of candles, lamps and gas-jets, or an aggregation of particles, as in the calcium light. Both of these methods have been used in the various systems of electric lighting. Electricity flowing through a conductor generates a quantity of heat proportioned 1, to the amount passing through, and 2, to the friction, or resistance, of the medium. Ordinarily, the amount is hardly appreciable in a good conductor. When, however, a poor conductor forms part of the electric circuit, a heat is generated that, under certain conditions, rises steadily to whiteness, causing the substance forming the imperfect conductor to become luminous. If the wire of an electric circuit be cut and the two ends, after being touched, are drawn slightly apart, the current leaps the chasm and a spark appears which vaporizes a small portion of the metal, and this forms a sufficient conductor to enable a constant electrical current to flow from end to end of the wire. When the two ends of the severed wire are properly tipped, a continuous and brilliant light may be produced. Carbon is found to be the best material for these tips, and so long as the current flows and the distance between the points is properly regulated, a storm of white-hot carbon particles is carried across the space, giving a brilliant illumination. This is the voltaic arc, a light produced by the incandescence of finely-divided matter. The broken circuit may be completed by the interposition of some solid matter capable of sustaining a white heat without melting. Platinum and carbon were long thought to be the forms of matter which would best answer the purpose.

These methods of utilizing electricity presented so many difficulties that it was thought impossible to use either for domestic purposes. The objections to the voltaic arc were that the carbon did not offer sufficient resistance to the passage of the current, and that it wasted, the light therefore requiring either continual attention, or else some complicated mechanism, both troublesome and expensive, to keep the distance between the carbon points constant. (See Fig. 3.) The objections to platinum lay in its great cost and rarity, and the fact that its point of fusion is too low to ensure its successful use as the source of light. And finally the objection to all known methods was that the conductors necessary to the supply of any lamp then known would have been of such enormous cost and size as to be impracticable for general use.

In order to understand the difficulties of the problem presented to Mr. Edison, and the simple perfection of his lamp, a short summary of the history of the electric light will be necessary. The first method of illuminating by electricity was by the voltaic arc. About twenty years after the discovery of galvanism, or the modes of generating electricity by chemical decomposition, the voltaic arc was discovered by Sir Humphrey Davy. The battery of a single cell was succeeded by those of multiplied power. In 1812, by the use of a battery of 2,000 cells, Davy succeeded in producing an intensely brilliant arc measuring five inches. The experiment was, however, a very costly one, and had apparently no practical outcome; yet the effects produced by it were so brilliant that Professor Dumas, who repeated it in Paris, in 1834, predicted its final success as an illuminant, in spite of the enormous cost—six dollars a minute. For a number of years no improvement was made, the batteries then in existence being incapable of supplying a constant and steady flow of electricity. Daniell's invention in 1836 of a constant battery, used still in telegraphy, and Grove's improvement in 1839, of electrical generators, gave a new impulse to inventors. A constant and powerful current being supplied by these two inventions, the practical use of it was shortly afterward made in Morse's telegraph. In 1845, about the same time, we find that the first mechanisms for regulating the distance between the carbon points were independently invented by Staite and Foucault, who thus in another direction utilized the electrical power supplied by the batteries. Staite's patents show great inventive genius; in one of them there is a well defined suggestion of the widely known Jablochkoff candles. In this field of research, as in so many others, the earlier investigators possessed a clearness of vision which enabled them to see further and more accurately than those who came after. Staite, before 1850, produced an electric light, which was exhibited in England, and was so favorably received that a company was organized and gas stock suffered a panic. Many other inventions were made, with a vast expenditure of time, ingenuity and patience, which, like those of Staite and Foucault, failed because of their great cost. It is not enough to invent a good light, nor even to perfect its mechanism: the cost of production must be small enough to enable it to compete with all existing methods of illuminating.

Electric lighting had now passed through three stages. It had been a brilliant laboratory experiment, it had been the subject of practical investigation, and it had been advanced to the precarious dignity of occasional use in the theaters and on great festal occasions. At the coronation of Alexander of Russia, the city of Moscow was lighted by numbers of electric lamps suspended in the old bell-tower of the Kremlin, a thousand gilded domes glittering in the unearthly radiance, in happy contrast with the quaint arches of the old cathedral close at hand, while the river Moskva was transmuted into a stream of liquid silver.

The year 1860 saw improvements in generators. The force of steam was found to be convertible into electricity. In 1862 Faraday introduced the electric lamp into a British light-house. France and Brazil tried the same experiment, but even this failed to arouse public interest. The invention of the Gramme generator (though an instrument fully anticipating it had been lying for years in the cabinet of a.. Italian university) at last gave the impetus needed to set the inventors at work. This was soon followed by the Jablochkoff candles, the contrivance by which some streets in Paris are illuminated. So much for the history of illumination by the voltaic arc.

In 1845, to go back to the second method,—that of illuminating by an incandescent solid,—an American named Starr, backed by

George Peabody, went to England, and took out a patent for the use of platinum, which had been already employed in laboratory experiments, although it had never been used for practical purposes. In the same year Grove speaks of reading by an incandescent platinum spiral.

In 1847, Dr. Draper, of New York, made a number of experiments to test the qualities of highly heated platinum. He used a lever suspended by a straight wire, very much resembling a door-latch held by a string. So marked was the illumination from, and the expansion of, the heated wire at the temperature required for the experiment that he wrote: "An ingenious artist would have very little difficulty, by taking advantage of the movement of the lever, in making a self-acting apparatus in which the platinum wire should be maintained at uniform temperature, notwithstanding any change taking place in the voltaic current." This suggestion, though so clear and practical, lay for twenty years unheeded, and would probably have done so much longer, but that Mr. Edison, with no knowledge of it, entirely independently made use of a similar device and proved himself to be the "ingenious artist," in his first electric light invention.

Fig. 1 shows the plan of the apparatus.*

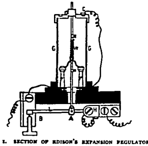

FIG. 1. SECTION OF EDISON'S EXPANSION REGULATOR.

The current enters through the curled wire at the left, and flows from one post, P, to the other, P', through a spiral and out at the right. It is carried to the top of the glass case, G, then through the straight wire, W, to the lever at A, then to the hinge, H, so that it escapes at the right. In passing through the straight piece of platinum wire, W, enclosed in the spiral the heat generated by the current causes the wire to expand. This expansion allows the lever, L, to fall until it touches the point, B. When this is done the electricity takes the short route through the lever and does not pass through the lamp. The wire, W, contracts and the process is repeated.

Another method of accomplishing the same purpose is shown in Fig. 2. The current passes, in this case, through the wire, W. In so doing it heats the air in G. The air

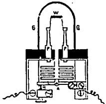

FIG. 2. EDISON'S PNEUMATIC REGULATOR.

in expanding forces downward the small metal bellows which is connected with the chamber, until the lever attached below closes the break, B, and short circuits the lamp, allowing the air to cool. These two inventions really belong to the infancy of electric lighting, though invented by Mr. Edison only a short time ago.

In 1849 Despretz describes a series of experiments on sticks of incandescent carbon which were sealed in a glass globe, the air being exhausted, or nitrogen substituted for it. He used several ingenious methods for holding the carbon—patented within the last few years.

So completely had the mode of lighting by an incandescent solid been forgotten, that in 1873 a medal was bestowed by the St. Petersburg Academy on Lodyguine for its supposed discovery, and letters-patent were granted to Sawyer and Mann for a stick of carbon rendered incandescent in nitrogen. No successful light by incandescence had, however, been produced when Mr. Edison began his experiments.

In 1878 the lighting of Paris by the Jablochkoff candles was creating a great stir. It had been proved that electricity was really a rival of gas, and that, especially where great concentration was needed, it could take its place. The question now was whether light could be produced in such small amounts as to make it of general domestic use. The money value of an invention which could compete with gas may be judged from the following items: The United States has $400,000,000 in-

* The portions marked black in the cuts are insulated.

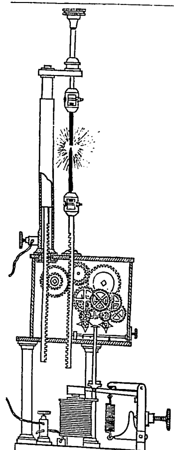

FIG. 3. FOUCAULT'S REGULATOR.

vested in gas, New York and the vicinity owning about $35,000,000 of this; England has $500,000, 00, $60,000,000 of which is in London. Paris has $40,000,000; Germany $50,000,000, etc. Capitalists, with these figures before them, and the further fact that notwithstanding the great depreciation in plant, the larger portion of this enormous capital was drawing ten per cent., were quick to see an opening for their money and enterprise. Several New York gentlemen, Mr. Grosvenor P. Lowrey and members of the eminent banking-house of Drexel, Morgan & Co. being the most prominent, placed $100,000 in cash at Mr. Edison's disposal, as the requisite means to make the research.

Mr. Edison came to the investigation unhampered by the blunders of his predecessors. He had never seen an electric light. He took hold of the subject in his usual clear-headed, practical way. Next to solving a problem, its intelligent statement is to an investigator the most important thing. Mr. Edison saw that permanence in the lamp and a subdivision of the light were the main things to be sought after. Of the two methods already described, he soon discarded the carbon arc. He perceived that from its nature this arc was inconstant, as its very existence depended upon the destruction of the carbon, and also that it presented greater difficulties in the way of subdivision. Even if he succeeded in conquering the latter difficulty, and was enabled to produce small lights, the carbon rods waste so rapidly that a system of such lamps would require an expert for every four or five houses to keep it in working order. The most effective apparatus then devised was Foucault's regulator, Fig. 3, which it will be seen is a very complicated piece of mechanism. The Jablochkoff candles, simple as they appear to be, require mechanical contrivances to light them and keep them burning, each candle lasting only a few hours, which makes the constant expense for new burners more than that of the electricity which they can utilize. Mr. Edison, therefore, concentrated his attention wholly upon the light from an incandescent solid.

The advantages of subdivision are twofold and may be explained in a few words. To show that a good gas jet or German student's lamp gives, near the source of light, all the illumination necessary for ordinary domestic purposes, a simple experiment may be tried. A printed page directly under the light, will be seen to be brightly illuminated. After carefully noting this, let another equally strong light be kindled. The room will be brighter, but the page will appear to be scarcely brighter. This is because beyond a certain limit the eye becomes insensible to light. One therefore gains nothing for ordinary use from a single intensely brilliant light. The object of such an illumination being of course to bring, by means of several moderate lights, all parts of the room up to that point where the eye, before it begins to be numb, can utilize the light. This explains the first advantage of subdivision; the second is of another kind. Every one familiar with the electric light, as it has been exhibited, knows that the intense brilliancy of the light and the sharp definition of the shadows, as well as their depth, makes it most trying to the eyes. The same amount of light distributed among a number of burners would not give more illumination, but it would be of more practical value, the light would be more diffused, the contrast between light and shadow less sharp and startling. Fig. 4 shows the effect of a shadow from a single brilliant carbon light, and Fig. 5 the effect from several shaded lights; the advantage of the latter for practical and domestic use will be readily seen. This is equally true with other illuminators; though gas may be made to give out a brighter illumination per cubic foot when burned in a concentrated form, it is yet more grateful to the eye and less trying when burned as a number of small lights, so that sharp contrast shall be avoided. It is also found that the shape and size of flame, apart from the quantity of light emitted, makes a great difference in this respect—a large light softening the edges of the shadows. The shading of a light, although it obstructs illumination, is useful in diffusing it.

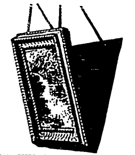

FIG. 4. EFFECT OF CARBON ARC ILLUMINATION

FIG. 5. EFFECT OF GENERAL ILLUMINATION.

As has been said, Mr. Edison came to the subject unhampered. He saw that subdivision was his goal, and toward that he steadily worked. With a steadfast faith in the fullness of Nature, a profound conviction that, if a new substance were demanded for the carrying out of some beneficial project, that substance need only be sought for, he set to work. Two examples of the reward of his faith may be mentioned. One of the great difficulties in the way of illuminating by an incandescent solid—a difficulty constantly urged as insuperable—was that platinum, though the most infusible material which could be drawn out into a wire, still melted at a temperature too low to insure its successful use. Mr. Edison, by experimenting, found that by slowly raising a piece of platinum to a white heat in a vacuum, he could make a practically new metal, the fusing-point was so greatly raised. Again, Mr. Preece, chief government electrician in England, declared, and was sustained by many others, that subdivision of the electric light was impossible, because of the enormous size of the conductors and the number of Faradic generators necessary. Edison simply introduced into his lamp an increase of friction or resistance to the electric flow, and the problem was solved.

Mr. Edison's idea in regard to the electric light was that, in all respects, it should take the place of gas. Following the analogy of water, the inventor conceived of a system which should resemble the Holly water works. As the water is pumped directly into pipes which convey it under pressure to the point where it is to be used, so the electricity is to be forced into the wires and delivered under pressure at its destination. In the case of water, after being used, it flows away by means of a sewer-pipe, and is lost. But it is easy to imagine that the water used in working machinery, for instance, instead of being lost, might be returned to the pumps and used over and over again. With such a system as this, we should have a perfect analogy to the Edison electric lighting system. The electricity, after being distributed under pressure and used, is returned to the central station. As the light results from no consumption of a material, but is mere transmutation of the energy exerted in the pumping process, it is therefore seen that all which is essential to an electric lighting system is the generator (or pump), the two lines of wire, one distributing the electricity, the other bringing it back, and a lamp which transmutes into light the energy carried by the electricity when it passes from one wire to the other, and in which the energy of the pressure expresses itself as the light. In Edison's invention the amount of electricity delivered in the lamp is determined by the size and resistance in the carbon, just as in water the amount of flow is determined by the size of the openings. As a great many small jets of water can be supplied from one pipe, so a great many lamps or small escapes for electricity can be furnished from one wire.

As in the case of water, the amount of work done by electricity—either as illuminant or motor—is dependent quite as much upon the pressure from which it escapes as upon the quantity passing through the wires. We might have a system of lamps which would give a certain amount of light from large quantities of electricity escaping under low pressure, or another system which could give an equal amount of light from a small quantity of electricity escaping under high pressure. As in either case the amount of electricity flowing through a wire is in proportion to the size of the wire, it will be readily seen that the application of pressure made by Mr. Edison obviates the main difficulty in the way of subdivision (*i. e.*, in the way of the domestic use of the electric light), namely, the enormous size and cost of conductors. The well-known principle of the effect of pressure upon the dynamic power of electricity had never been utilized because the proper lamp was still unknown. This lamp is Mr. Edison's main discovery. In order to utilize this, one of the plans devised by him was to make the flow of electricity intermittent. Enough was allowed to escape in a short time, say one-third, to keep the lamp all the time supplied. It of course would require a large wire to furnish the quantity of electricity needed, yet two-thirds of the time the wire would be inactive, during which period it could be used to supply two other lamps constructed on the same principle. According to the doctrine of probabilities, one-third of a large number of lamps would be in use all the time. Such being the case, the cost of a conductor would be divided among three lamps. The lamps were so constructed as to burn steadily all the while, although the electricity was passing through them only one-third of the time.

One form of apparatus for accomplishing this distribution among several lamps on the same electrical circuit is shown in Fig. 6. The current conducted by a single wire enters the wire, O, from the lower left hand corner and flows through the spring, S, by way of B and B; upward through O, around the magnets, M, M, and out through the lamp B, B, are two points where the circuit can be broken if the spring, S, is depressed. Two points are made in order that the spark caused by the breaking of the circuit may be made less by division. The spring S is de-

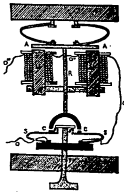

FIG. 6 EDISON'S VIBRATING REGULATOR.

pressed by the arms, C, C, which are attached to the armature, A, by the rod, R. The action is as follows: The current renders the magnet active, it attracts the armature, A, and presses the spring, S, under, stopping the flow of electricity by breaking the circuit at B B. The magnet thus losing its power, the armature is drawn back by the spring to which it is attached and the apparatus is ready to work again. The period of this vibration may be regulated by means of a screw underneath, which can make the excursion of the armature more or less before it breaks the circuit, or can even act to break the circuit itself.

In making an electric lamp which would be efficient without a regulator (as is Mr. Edison's later invention), two things are essential, great resistance in the wire, and a small radiating surface. Mr. Edison sought to combine these two essential conditions by using a considerable quantity of insulated platinum wire wound like thread on a spool. This arrangement is

shown in Fig. 7. The spool was made of zircon, pressed extremely hard, and was to be suspended in an exhausted glass bulb by two leading-wires. The platinum, as has been incidentally mentioned, was hardened by alternate heating and cooling in *vacuo*, which is done by passing electricity through it till white heat is reached and then cutting it suddenly off. A theory is that the sudden cooling contracts the metal and squeezes out the air contained in it.

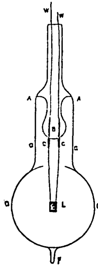

FIG. 7. EDISON'S PLATINUM LAMP. HALF SIZE.

One of Mr. Edison's greatest difficulties was to get a substance with which to insulate his wires that would not melt and also become a conductor in the intense heat generated by the current,—in which case the electrical flow instead of traversing the whole length of the wire would flow across from layer to layer, or sidewise from wire to wire. This difficulty diverted his attention from platinum to carbon, which is infusible. He did not suspect, at first, that it could be made to offer sufficient resistance to the passage of the electric current, and that through it he was to reach a happy solution of the entire problem. A long time was spent, with a fair degree of success, in seeking to make a spiral of lamp-black tar in the form of a wire. To hold this together he used a bit of ordinary sewing cotton which was covered with lamp-black, and succeeded in producing from an inch and a half of this simple thread, bent into an arch, a light equal to an ordinary gas-jet. The lamp-black, however, contained air, which greatly interfered with the success of the method. He then used a simple thread, which he found to answer the purpose, though it presented the objection of being fragile, uneven in texture, and unmanageable. This difficulty suggested the use of charred paper, cut into a thread-like form. The difficulties apparently so insuperable melted away. The electric lamp was completed. A piece of charred paper cut into horse-shoe shape, so delicate that it looked like a fine wire, firmly

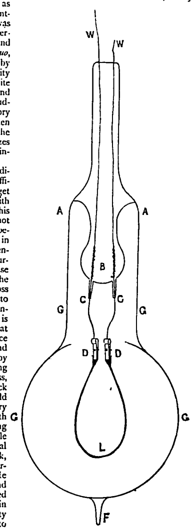

FIG. 8. EDISON'S ELECTRIC LAMP. EXACT SIZE.

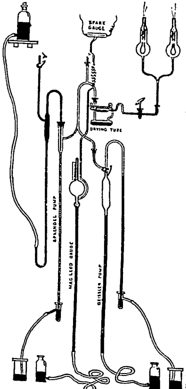

FIG. 9. MERCURY PUMPS FOR PRODUCING VACUUMS.

clamped to the two ends of the conducting and discharging wires so as to form part of the electric circuit, proved to be the long-sought combination. From this a light, equal in power to twelve gas-jets, may be obtained. Fig. 8.

The process by which the paper is rendered serviceable is also extremely simple and inexpensive. The horse shoe loops are cut from card-board and placed in layers, within an iron box, with tissue-paper between; the box is hermetically sealed, and then raised to a red heat. Nothing remains but the carbon loops and the carbonized tissue-paper. All other forms of carbon previously used had presented the difficulty of containing air or gas. The carbonized paper, however, is found to be perfectly homogeneous in structure, elastic, tough, and of an almost vitreous cleavage. It is strong enough to stand far more strain than will be put upon it in any ordinary use. If this paper were burned in air, or in a vacuum prepared by a common air-pump, it would of course be almost instantly destroyed. In a high vacuum it burns, but is never consumed. The small glass globe which holds the simple apparatus is exhausted of air by means of nearly the same combination of the Sprengel and Geissler mercury pumps used by Crookes in making his radiometer, or "light mill," and in his wonderful discovery of the phenomena of radiant matter in high vacuums, recently brought before the Royal Society of England. Much attention has been bestowed of late on the question of securing good vacuums. An absolutely perfect one is unattainable. It is, however, found that by the use of the mercury pumps and chemical appliances, where a nearly perfect vacuum is formed, the minute portion of air remaining shows some remarkable properties. When electricity understrong pressure passes through an Edison lamp, the whole bulb shines with a delicate blue light. So remarkable is the behavior of various substances in a vacuum prepared by means of mercury pumps, that physicists consider that a gas thus rarefied constitutes another state of matter, differing as much from that of an ordinary gas (either under atmospheric pressure or with the pressure removed by means of a common air pump) as a gas differs from a liquid, or a liquid from a solid. Mr. Edison's use of carbon in such a vacuum is entirely new.

The pumps are shown in Fig. 9; the Geissler pump is to the right and below. By raising a bottle which is connected with it, the air is forced out of a large glass bulb, and allowed to escape through the tube A. On lowering the bottle, the mercury flows back into it, leaving a vacuum in the bulb. The opening of a stop-cock allows some of the air which is left in the pump to flow into this bulb, when the air is again forced out as described; this is continued until the air is exhausted. The working principle of the Sprengel pump is the continuous dropping of mercury through a tube, each drop acting as a piston, carrying before it a small quantity of air. As there is no return stroke, even by the aid of a small tube, the work of exhaustion goes on

quite rapidly. The MacLeod gauge in the center is so constructed that it will measure with exactness when less than one-millionth of the original air is left in the pump.

Another purpose besides that of preventing the destruction of the carbon is served by burning it in a vacuum. Almost all the electricity is converted into light, very little being dissipated by convection or conduction as heat. The little glass globe only an inch from this brilliant light remains cool enough to be handled, and does not scorch tissue-paper wrapped closely around it.

Fig. 8 shows the lamp of its actual size. The current enters it by one of the wires, W. At B this copper wire is twisted and soldered to a platinum wire, which passes through the glass at C, and by means of a small platinum clamp into the horse-shoe, L, from which, by as simple a route as it entered, it returns. L, the source of light, was made in the form of a horse-shoe, in order to approximate to the shape of a gas-jet, and is large enough to cause the edges of the shadows to be softened down, and so obviates the common objection to familiar forms of electric lighting. The carbon is sealed in a glass bulb, G G G, the knob of glass, F, is the melted extremity of the tube by means of which the bulb was connected with the pumps. At the points, C, C, where the platinum wires are sealed into the bulb, some trouble was occasioned by the cracking of the glass, which allowed air to leak into the bulb. It will be noticed that the glass is now drawn up around the wire in a thin tube. This is found to heat and cool so rapidly that it is practically homogeneous with the wire, and even if the wire be heated red-hot it will not break. Mr. Edison has tried putting a lamp alternately on and off the circuit for several hours by means of a telegraph key, without loosening the wire. This experiment was equivalent to using the lamp several thousand times.

Mr. Edison has thus succeeded in making a lamp of the simplest imaginable construction, and of materials whose expense is extremely small. The paper costs next to nothing, the glass globes very little, and the platinum tips of the wires are so small that, though the metal used is expensive, their cost is trifling. The test of the value of every invention is its simplicity, and this is the crowning characteristic of Mr. Edison's lamp, for it is really nothing more than a piece of wire looped into a glass globe.

The lamp being complete, let us consider the generator [Fig. 10], for which Mr. Edison has proposed the name Faradic, in honor of the great physicist.

The cylinder which is placed below, between the blocks of iron, F, on which the

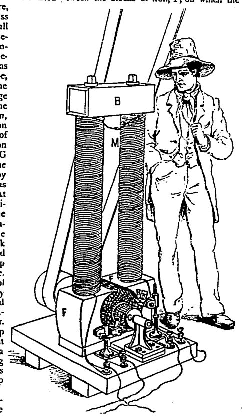

FIG. 10. FARADIC GENERATOR.

magnets, M, rest, is called the armature, and is so arranged that it can be made to revolve rapidly by means of a belt. This armature consists of a small cylinder of wood, which is wound around with iron wire as thread is wound on a spool, the ends being made as in a spool, to hold the wire in place. Around the whole spool are a number of loops of copper wire, covered with cotton thread, running lengthwise of the armature. The ends of these loops may be seen as they are taken from the armature to the cylinder, C, which is an extension of the armature, by which the currents generated in the copper wire may be taken away from the machine. This cylinder, called the commutator, consists of blocks of copper that really represent the ends of the wire, which are placed side by side around the axis of the cylinder in such a manner that no current can pass from one to the other. Touching these as they revolve are brushes, R, made of copper wire, by means of which the electricity flows from the machine.

That the wire about the armature may be able to pump electricity into the line, it is needful that it be revolved immediately in front of magnets. The magnets are made of such large dimensions that the electricity, which is pumped through the machine, may meet with as little friction as possible in passing through the wire of the armature, since by means of the great strength of the magnets, very little wire can be made extremely powerful in forcing the electricity to a higher level or in putting it under pressure. It is exactly as in pumping water, if we have a poor pump (analogous to a machine with a poor magnet) the water may meet with an enormous friction in the pump itself, or require two or more, perhaps, to give it the required pressure, while in a good pump all the parts are so made that while great pressure is given to the water, it passes through it with the utmost freedom. The machine has such strength that it is intended to use only a small fraction of the power, which it could convert into electricity, and deliver outside.

It is proposed to mass a large number of such machines, as in Fig. 11, and have them all pump electricity up from one wire into a second. The two large wires, held on supports above the floor, are intended, the one to carry the electricity away, and the other to bring it back after it has been used. Two machines are placed at one side; these are for the purpose of rendering active the magnets of all the others.

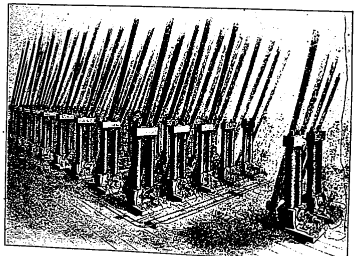

FIG. 11. PROPOSED CENTRAL STATION.

It is proposed to establish such stations in the course of a few months in the heart of several of our large cities. These will supply houses for quite a distance around them. 1,000 horse-power is thought to be a sufficient amount for a unit, and the stations will be at such distances from one another that each district will require about this amount. The engines will be divided into four groups of 250 horse-power each, with a spare one in each station of the same power.

The wires will be laid in fascines or bundles under the edge of the sidewalk in a tight box. The object of this is to make them easy of access and easy to place in position. Nor is there need of putting them out of the reach of the frost, for they are continuous and not liable to leak from change in position. Even more important is the fact that the colder the wires are the less is the waste of electricity, thus giving a decided advantage over gas in winter, when most light is needed.

The main wires may be either of iron or copper according to the market price of these metals; as quotations are to-day the preference is slightly in favor of copper wire. These lines of wire will start from the central station and send out branches in the same manner that gas or water pipes diverge, growing smaller the farther they are removed from the central station. Fig. 12 also shows the branch wires as they enter the house. It is proposed to color the distributing wires red and the waste wires green. These two distinct wires will be carried all through the house, and every lamp will be so placed that the electricity will flow through it from one wire to the other.

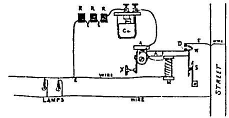

FIG. 12. DIAGRAM OF METER AND SYSTEM.

Before passing into the house, the electricity is carried through a sort of meter containing a safety-valve, by means of which it can be measured. The contrivances for doing this are shown in diagram, in Fig. 12, and in perspective in Fig. 13. The lettering is the same in both for identical parts. The current enters at E, passes through the two platinum points, D, then through the armature, A, to the dividing points, P P. The larger portion of the current then flows around the magnet, M. The armature above the magnet is held from it by means of the spring, X. The object of the device is to furnish a means of cutting out a house if too large a flow of electricity by any accident should occur. The magnet would then be capable of drawing down the armature which would separate the platinum points, D, and break the circuit.

The small wire, W, serves a double purpose and is a remarkably clever solution of a double problem. First: If the circuit were partly opened it would weaken the magnet, and the armature would recede, closing the circuit. It would thus form a vibrator resembling Fig. 6. The wire, W, allows enough electricity to pass to close the snap, S, so that the armature is firmly held in place, after which the wire, W, will melt off and completely break the flow of electricity. Secondly, the wire serves another purpose:

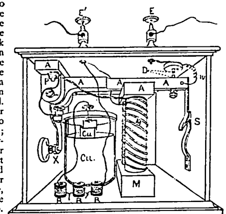

FIG. 13. EDISON'S ELECTRIC LIGHT METER.

if the points were drawn apart an arc would spring between them. The wire, W, conducts the electricity by a shorter route than that offered by an arc and so keeps the space between the two points free from the intensely heated vapors of the metal.

A small fraction of the current passes by another route to the lamps, from the point P. It first traverses a length of wire wound on small spools marked R. The amount placed here will regulate the flow through this line. The current next passes through from one copper plate marked Cu to another, through a solution of copper salt. In thus flowing, for every unit of current a certain amount of copper is deposited on a thin sheet, the amount for a lamp being once determined by burning one for a number of hours. It must be remembered that only a small amount passes through the meter, but that which passes is proportionate to the whole. It is proposed to make a standard lamp, which shall give a light equal to that from a gas flame consuming five cubic feet each hour. From this it will be calculated how much copper will be deposited, and the amount will be said to represent five cubic feet. The bills for electricity will be made out in 1,000 feet, as in the case of gas. The inspector will take the strip on which the copper is deposited to the central station, in order to determine the amount of electricity used.

Besides giving light, the electricity supplies a convenient form of motor for domestic purposes. A small electrical engine placed beside a sewing-machine, for example, and connected with the distributing wire, may save all the fatigue of treading the machine, at an expense exactly equal to that of one jet burning for the same time. Elevators may be lifted, lathes turned, and instruments operated up to several horse-power, by this same means. Fig. 14 shows the form adopted by Mr. Edison. It is substantially a small model of the large Faradic machine, the only change being in the fact that the armature, C, is placed lengthwise of the magnets, MM, instead of across them. At S is a switch by means of which the motor can be started or stopped. It is expected that the amount of power used in the day time will largely pay for the expenses of generating—an additional advantage over gas.

In order to use the lamp, it is brought into the circuit by turning a handle in a certain direction, or thrown out by reversing the motion, or by means of plugs, which are inserted in a socket. This may be done either in the chandelier or in any other convenient place in the house. Very simple arrangements may be made so that by touching a knob by the bedside the whole house may be brilliantly lighted for the reception or discovery of a suspected burglar. Of course, no matches have to be used; the light kindles itself by the turning of a handle, and so one fruitful source of destructive fires is avoided.

In order that the philosophical relations of the processes may be understood it is needful to trace the history of the energy as it is taken from the coal and conveyed over the wire to the lamp. A large portion of the heat produced by the combustion of the coal under the boiler is found in the steam as it flows to the engine. By means of the latter a small fraction, about ten per cent. of the original energy, is transformed into the motion of the wheels attached to the engine. It may be traced as it flows through the belt to the shaft, and again as it is carried from the shaft to any machine which it may drive. A belt exactly resembles, in carrying power, a man pulling a shaft around by means of a rope. The amount he is pulling can be measured by the strain on the belt, and the work he is doing by determining the speed with which he carries the end of the rope. Mr. Edison has made a device, represented by Fig. 15, to measure this strain.

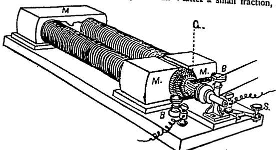

FIG. 14. EDISON'S ELECTRIC MOTOR.

The belt starting from the pulley over the main shaft, C, is carried under a pulley, A, which is attached to a large box containing heavy weights. This box is placed upon a platform scale. The belt then runs over pulley, D, which it has to drive, and under a wheel, B, which rests heavily upon what would otherwise be the slack part of the belt, for the purpose of tightening it. The pulley, A, attached to the weight, will have a tendency to be drawn upward by any strain that may be put on the belt, just as the block of a tackle is drawn up when the rope is tightened which runs through it. The weight lifted may be measured by the diminution of weight on the scale, one half of which gives the strain on the belt. Fig. 15 also shows the arrangement of machines as they were placed in order to be tested. The cones D and E were for the purpose of changing the speeds at which the machines were run. The machine, H, at the right, renders active the field of the other machine, F; the current may be regulated by passing through more or less of the resistance boxes, R. By means of this apparatus the exact amount of power carried by the belt can be reckoned when its speed is known. This latter measurement is made from the main shaft.

The energy which the belt carries is seemingly lost, as material motion, when it has turned the armature of the Faradic machine. Since this seems to be a point where the majority lose the track of the energy, in order to explain clearly allusion must be made to some fundamental experiments. Arago many years ago tried this experiment: a sheet of copper, which is not attracted by the magnet under ordinary conditions, was passed between the two poles of a powerful magnet, and it was found to be retarded in its motion. If the magnets are extremely strong, though the copper sheet to the eye passes through nothing but air, yet to the hand it seems as if it were cutting cheese, so strong is the

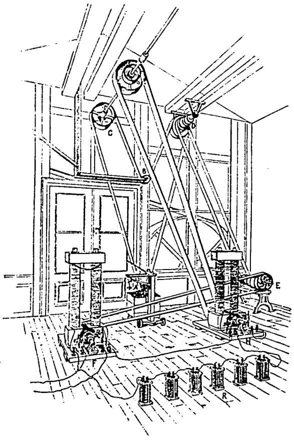

FIG. 15. EDISON'S DYNAMOMETER, FOR MEASURING THE FORCE OF AN ELECTRIC CURRENT.

drag put upon the copper. This phenomenon Tyndall calls the apparent viscosity of the magnetic field. Faraday, a few years after this discovery, clearly explained the reason for seeming friction between the plate of copper and the invisible lines of magnetic force which he imagined to reach out from every magnet. He used wires and passed them in front of the magnet, and found that whenever they were made to cut these lines electricity was thrown into the wire. This grand discovery is at the basis of all that is now done in making strong currents, for it furnishes the method by which motion of mass may be transformed into the molecular motion called electricity.

As the energy appears in the wire, it is measured again by an electrical dynamometer, the main idea of which was that of Professor Trowbridge, of Harvard University.

By means of the two instruments, one is enabled to trace out the amount of energy absorbed and given back by the machine, and in many cases ninety per cent. of the original power applied is found converted into electricity. A system of electric lighting is nothing more than a gas system, where energy takes the place of vapors.

It is one of the laws of progress, that no sooner is a method for producing a certain result perfected than a practical use of it follows. This is attested by the history of many great inventions. Following out the laws of discovery, it has been for some time a speculation of the writer that the wonderful perfection to which vacuums had been brought, pointed historically toward some direct connection between them and the electric lamp. For the past few years no more striking result of scientific work has been effected than the startling phenomena shown in high vacuums; parallel with this, a growing want has been felt for a cheaper and more efficient mode of illuminating. Is this a mere coincidence? or may we believe that the demand and means of supply have been developing independently, but side by side; and that now in the electric light we find a practical application of what had been reached by purely theoretical research?

Besides the enormous practical value of the electric light, as domestic illuminant and motor, it furnishes a most striking and beautiful illustration of the convertibility of force. Mr. Edison's system of lighting gives a completed cycle of change. The sunlight poured upon the rank vegetation of the carboniferous forests, was gathered and stored up, and has been waiting through the ages to be converted again into light. The latent force accumulated during the primeval days, and garnered up in the coal beds, is converted, after passing in the steam-engine through the phases of chemical, molecular and mechanical force, into electricity, which only waits the touch of the inventor's genius to flash out into a million domestic suns to illuminate a myriad homes.

"THAT LASS O' LOWRIE'S."

LIKE those grand heights of far-off northern lands
(With desolation at their skirts), which bare
Their brows to radiance of transcendent air,
Majestic in her loneliness she stands—
Yet tender to a touch: with craving hands
That draw a slighted baby's mouth to share
The sweetness of her lips, in kisses rare
Of love her own defrauded life demands.
What matchless courage sets her steadfast feet
Along their path of thorns! She, hopeless, takes
Her pain, her love, all hopes most sweet and near,
And goes—unwittingly—crowning joy to meet!
The Joan of our love! whose story makes
Our true and tender womanhood more dear.

Complainant's Exhibit "Nature Publication of February 12, 1880." Feby. 28, 1890. S. M. H. Exr.

"NATURE," VOL. 21, PP. 341-342.

London, February 12, 1880.

Editorial.

EDISON AND THE ELECTRIC LIGHT.

Mr. Edison has once more come forward with an electric lamp, which we are assured solves the problem of the economic subdivision of the electric light. We have heard this statement so many times with respect to one form or other of lamp devised by this most ingenious and indefatigable inventor, each of which in turn has come to no tangible result, that it becomes harder than ever to trust to the rash announcements flourished so airily by the newspaper press on both sides of the Atlantic.

What is then the nature of the invention thus heralded before the world? Regarded quietly, and without prejudice, from a scientific standpoint, what is the value of the discoveries which can thus play havoc on the Stock Exchange?

A recent number of the "*New York Herald*" contained a long and detailed history of Edison's experiments on electric lighting, from which the following description of the new lamp is taken:

"With a suitable punch there is cut from a piece of 'Bristol' cardboard a strip of the same in the form of a miniature horseshoe, about two inches in length and one-eighth of an inch in width. A number of these strips are laid flatwise in a wrought iron mould about the size of the hand and separated from each other by tissue paper. The mould is then covered and placed in an oven, where it is gradually raised to a temperature of about six hundred degrees Fahrenheit. This allows the volatile portions of the paper to pass away. The mould is then placed in the furnace and heated almost to a white heat, and then removed and allowed to cool gradnally. On opening the mould the charred remains of the little horseshoe cardboard are found. It (sic) must be taken out with the greatest care, else it will fall to pieces. After being removed from the mould it is placed in a little globe and attached to the wires leading to the generating machine. The globe is then connected with an air-pump, and the latter is at once set to work extracting the air. After the air has been extracted the globe is sealed, and the lamp is ready for use. * * * The entire cost of constructing them is not more than twenty-five cents."

Since the date of this article a paper has seen published in "*Scribner's Monthly Magazine*" for February, written by Mr. Upton ("Mr. Edison's mathematician") but attested by Mr. Edison's signature as the "first correct and authoritative account" of the invention, which confirms the "*Herald*" article to the minutest details.

We fear Mr. Edison is thirty-five years behind the time in his new invention. The patent-roll of Great Britian for 1845 contains the specification of a lamp invented by King, in which a thin rod of carbon was placed in an exhausted globe; and the inventor specially dwells on the advantage of the Torrecellian vacuum for the purpose. A similar lamp was designed by Lodyguine in 1873. The only difference between these lamps and that now brought forward is that Edison prefers a different and apparently less durable kind of prepared carbon to that employed by his predecessors, though, again, in the employment of carbonized paper he has been more than once anticipated.

We need not animadvert on the reckless and amusing statements made by newspaper correspondents and interviewers; for these accounts, we believe, Mr. Edison cannot be held responsible. Mr. Edison's first steps in electric lightning, we are told, were to invent a lamp and a generator. The lamp consisted of a piece of platinum to be made incandescent, and so arranged that any excess of heat would cause a small lever to cut off the current. It was an old device described by Draper in 1847. The generator was, on the other

hand, a startling novelty. Instead of causing, as in all ordinary dynamo-electric machines, a set of coils to revolve about an axis in a magnetic field, Edison proposed to mount the coils upon the prongs of a huge tuning-fork which should be vibrated by a steam engine. The friction and waste of power inseparable from rotation was to be completely abolished. Unfortunately "the machine was not practical and it was laid aside." In other words, it was a hopeless failure, wrong in design, wrong in principle, useful only in showing how singularly devoid of sound scientific knowledge a clever practical man may be. The next idea was to make the incandescent metallic strip give light by proxy, causing it to communicate its heat, either directly or by the intervention of reflectors, to a piece of lime or zircon. The fusible nature of platinum, however, spoiled his efforts, and he proposed expensive alloys of iridium and osmium, only to find, what all experimentors with indandescent metals had long known, that there is a constant disintegration going on at the surface and a consequent waste. Mr. Edison discovered, what is for every student of the theory of electricity the most simple and obvious conclusion from Joule's law, namely, "that economy in the production of light from incandescence demanded that the incandescent substance should offer a very great resistance to the passage of the electric current." Forthwith the spirals of platinum, iridium and iridio-osmium were thrown aside. A carbon filament prepared from charred paper, as described, was adopted. It will be difficult to convince us that the fragile horseshoe paper cinder will resist disintegration better than the carbon used in exhausted tubes by dozens of other experimentors; indeed, the invention is avowedly so recent that no lamp can have been tried for a period long enough to warrant an assertion of its permanence. The latest telegrams from the States inform us that Edison finds great difficulty in maintaining good vacua, and that further experiments are necessary. It must not be forgotten that even in a globe exhausted to one-millionth of an atmosphere there yet remain many millions of millions of molecules of air enough to make the disintegration of the incandesent carbon fibre only a question of time.

Meantime Edison had "discovered" what had been known in Europe for many months—that mercurial air pumps could be constructed to exhaust to one-millionth of an atmosphere; and what is more to the point, he found a workman formerly in the employ of the late Herr Geissler, of Bonn, to make his pumps and glass bulbs for him. The tuning-fork generator had already been abandoned in favor of a new generator, christened the Faradic machine, which embodied no new principle, nor indeed any very important improvement in construction, being essentially a modification of the well-known Siemens machine, having a longitudinally-wound armature rotating between the poles of a powerful electro-magnet, which in this new form is vertical and provided with unusually massive cheeks.

One detail of construction is, however, singular, though it seems to have escaped the notice of electricians. Beneath the longitudinal strands of covered wire the central core of the armature, which is of wood, is overspun with a few layers of iron wire wound transversely. This layer of iron resembles in a kind of way the iron ring in the armature of the Gramme machine, and though no conducting wires traverse the interior of it, it clearly may serve one of the important functions of the iron ring in the Gramme machine in concentrating the lines of force in the field. In support of the allegation that this machine gives out in electricity 90 per cent. of the energy it receives from the driving engine, Mr. Edison caused certain calculations by Mr. Upton to be published in the *Scientific American*. We have examined these calculations and find that they are based on the supposition that the electro-motive force of the generator is a constant quantity when the speed of revolution is constant, and independent of the resistance of the circuit and of the quantity of current generated. This can only be true if the field magnets are excited by a separate current and generator. Now, in the numerical calculations

which have thus been put forth *in proof* of the above assertion, there is no statement made as to the power necessary to supply this auxiliary current, nor indeed are any statistics whatever given of the actual power (in foot pounds or any other measure) delivered by the driving engine to the generator; only a cut-and-dry calculation to show that if the external resistance be greater than the internal the machine will theoretically work more economically when not generating the maximum current. In the *Scribner* article it is explicitly stated that a second Faradic machine is used to render active the magnets of the machine which supplies the light, and in two admirable pictures, one of which is a view of the battery of Faradic machines set up in a "central station," the nature of the arrangement is shown.

We need not refer in detail to the enthusiastic inconsistencies in the *Times* correspondent's accounts. Upon Edison's own data, electricity, instead of costing one-fortieth of the price of gas, costs at least seven-eighths as much, or about thirty-five times as dear as the *Times* correspondent declares. As to the cost of the lamp itself, with its carefully incinerated horseshoe of paper, its glass globe exhausted to one-millionth of an atmosphere, and its platinum-connecting wires, we confess we do not know where the work could be done for anything like the cost of a shilling. "The current can be transmitted on wire as small as No. 36,' says the *Times* reporter, who, probably being unaware that the resistance of a yard of such wire is at least half an ohm, avoids saying what length of such wire may be used. With a generating machine "in a central station, perhaps a half-mile away," the introduction of 400 ohms' resistance would be serious—to the light.

But apart from the mild absurdities of newspaper correspondents, the more we study the detailed accounts of the new inventions the more we regret that Mr. Edison does not devote some time to learn what has been already done in this field. An inventor who ignores what has been done ought not to be mortified to find himself occasionally forestalled by others in some discovery which he prides himself is his own. Possibly this may explain the inability sometimes shown by an inventor to credit the good faith of a rival who has priority. The worst feature of such a course of thought lies in its absolute incompatibility with a truly scientific spirit. Here the scientific man and the inventor part company, since the habits of accurate thinking and the necessary candor of the scientific method preclude the truly scientific man from ignoring, even for the sake of scientific discovery, that which is already a part of scientific truth. We are doing no injustice to Mr. Edison's splendid genius when we say that it is to the character of the inventor, not to that of the scientific thinker, that he aspires.

What shall we say, finally, to the whole system of these reckless newspaper announcements—for which, as we have said, we ought not to hold Mr. Edison responsible—by which the public mind is periodically fluttered?

The remedy to these things is obvious enough. Let scientific men once and for all repudiate these false and unwholesome displays of ignorance. Let public opinion insist that the inventor shall be allowed to pursue his way unhampered by the officious interference of the unprincipled speculators whom his soul abhors, or by the irrepressible unscientific reporter, who is only one degree less reprehensible for the part he plays. Whether the latest forms of invention are doomed to the fate of their predecessors or not, the man who can struggle against failures and discouragements as indomitably as Edison has done deserves to succeed, however erratic his methods. But if he succeeds ultimately, it will be in spite of the vampires of the Stock Exchange and the hangers-on of the New York press, who dog his steps for their own selfish ends.

Complainant's Exhibit "Engineer" Article of February 13, 1880. S. M. H. Exr.

Extracts from "The Engineer," February 13, 1880, p. 126. Under the heading:

"Mr. Edison on Electric Light."

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"Either, as we have said, Mr. Edison and Mr. Upton know little or nothing of electric lighting or else they have put forward statements which are in advance of facts, and that knowingly and of set purpose." * * * "But he understands so little the questions involved in the production of the electric light that he has failed to see the consequences which must ensue from the fact that if the resistance be increased, the power must be increased also."

* * * * * *

"We have said nothing of Mr. Edison's schemes for lighting towns from central stations, as set forth by Mr. Upton. 'It is proposed,' he says, 'to establish such stations in the course of a few months in the heart of several of our large cities. These will supply houses for quite a distance around them; 1000 horse-power is thought to be sufficient amount for a unit, and the stations will be at such distances from one another that each district will require about this amount. The engines will be divided into four groups of 250 horse-power each, with a spare one in each station of the same power.' Seeing that five lights would require one horse-power indicated, and that twenty 16-candle burners per horse is certainly not a high average, it is evident that engines of 1000 horse-power could not supply more than 200 houses, or say a single street of very moderate dimensions. Thus at every turn the moment Mr. Upton's statements are submitted to the test of calculation they break down or appear in the light of wild vaticinations, hardly deserving serious attention."

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Complainant's Exhibit "Outerbridge Account of Edison Lamp of January, 1880." S. M. H., Exr.

JOURNAL OF THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

Vol. CIX. March, 1880. No. 3.

(Third Series. Vol. LXXIX.) p. 145.

THE EDISON ELECTRIC LIGHT.

Proceedings of the Meeting of the Institute, January 21st.

Mr. A. E. Outerbridge, Jr., made the following remarks:

MR. CHAIRMAN AND GENTLEMEN—In acceding to the request of the Secretary of the Institute that I should give the members an account of my recent visit to Menlo Park, and the system of electric lighting now being practically tested there, I wish to premise that I do not feel especially well qualified by reason of any superior technical knowledge or experience to do full justice to this most interesting topic, in regard to which there exists a great diversity of opinion among the doctors. I shall not, therefore, venture to express any opinion as to the originality of Mr. Edison's devices or the possible future economy or practicability of his light. I shall merely endeavor to describe, as concisely as possible, for the benefit of our members who may not have had an opportunity of seeing this light, the general plan of operations as I observed it at Menlo Park, and to present a resumé of the history of the matter to be discussed this evening.

It is scarcely necessary for me to explain to you that the problem which Mr. Edison has been endeavoring to solve for the past two years has been the production of an electric illumination by the system known as "incandescence" of a solid material, as distinguished from the electric arc between the carbon pencils, with which

we are all so familiar. That this problem is by no means a new one, many of you know, and Mr. Edison is not, and does not claim to be, the pioneer in this field of research. As long ago as 1845 an American inventor named Starr obtained a patent in England for a system of incandescent electric lighting, the specification reading almost like a description of Mr. Edison's apparatus.[1]

Starr's schemes were prematurely extinguished on account of his sudden death, but he was followed by a number of others who produced incandescent lamps depending on the same principles, all of them promising in their embryonic stage brilliant prospects of future usefulness, but they have all failed to fulfill the expectations of their sanguine authors; and have remained buried in almost complete oblivion[2]. It is not unnatural, therefore, that scientists who are cognizant of the immense difficulties in the way of a practical solution of a problem which is, in theory, extremely simple, should hesitate to concede a better fortune to this latest child of even so herculean an inventive genius as Mr. Edison.

The earlier workers in this field relied entirely upon the expensive consumption of zinc in the galvanic battery for their source of electricity, and it is difficult to conceive, under such circumstances, that an incandescent light, even though perfect in all other respects, could have been made an economical success as compared with gas or other illuminants.

The electrical force is now obtained very much more cheaply by consuming coal in a steam engine, the mechanical force of the engine being converted into electrical force by means of the powerful dynamo-electric machines. Here, too, great activity has been displayed of late years among inventors in the improvement of these machines, and the modern machines convert mechanical into electrical power as economically, compared to the older forms, as the modern turbine wheel compares with the ancient overshot water wheel, in respect to its saving of energy.

The dynamo machines all depend upon the principle promulgated by Faraday, that when a piece of metal (as a wire) is moved between the poles of a magnet (or cuts the field of magnetic force, is its technical term), a pulse of electricity flows in one direction while the wire is under the influence of the magnet, and returns in the opposite direction when it is removed from the sphere of attraction.

The earlier forms of magneto-electrical machine—those of Pixii, Saxton, Clarke and others—consisted essentially of a permanent horseshoe magnet of steel, in front of the poles of which were two bobbins or spools of insulated copper wire, wrapped in opposite directions on a soft iron core, and mounted upon a horizontal axis which was turned by a handle. "When the bobbins "were revolved, the two spools became alternately "magnetized in contrary directions under the influence "of the magnet, and in each spool an induced current "was produced, the direction of which changed at each "half turn."

A simple improvement, called the "commutator," was soon made, by which the two alternating currents were forced to flow into a conducting wire always in the same direction. The earlier machines were only made to produce feeble and intermittent pulses of electricity until the apparatus of Nollet, of Brussells, constructed in 1850, worked a revolution and partially revealed the latent capacities of the principles involved in the apparatus. This machine consisted of forty powerful horseshoe magnets (capable of sustaining 125 pounds weight each), mounted radially on a cast iron frame. On a horizontal axis, running through the frame between the poles of the magnets, were four wheels, upon whose peripheries were placed 64 spools of insulated fine copper wire. The wire on all the spools was coiled in the same direction, and the spools could be connected so as to produce at pleasure electricity of high potential or of low tension, just as the different cells of a galvanic battery may be connected to produce similar variations of electrical condition. This machine was run by steam power and sustained an electric arc which measured, photometrically, equal to 150 Carcel burners.

The next degree of advance was made in the production of the Siemens armature, in which the wire was wrapped longitudinally on an axis, instead of transversely, as in the bobbins.

Then came Wild's machine, which combined the Siemens armature with a new principle, that of the "multiplication of the current." The current induced in the armature is used to charge a large field magnet (electro-magnet), between the poles of which a large Siemens armature was revolved at the rate of 1,700 revolutions per minute.

Next came Ladd's modification, in which two Siemens armatures were used, and the permanent magnets were dispensed with altogether. Mr. Ladd found that if the large electro-magnet was once charged with electricity from a battery or other source, sufficient residual magnetism remained ever afterwards in the soft iron cores to act upon the armature and produce a feeble current in it as long as it was revolved.

This current was then passed into the coils of wire forming the large field magnet, increasing its strength; this in turn reacted on the armature, and so, in a few moments, a very powerful effect was produced by the building up, as it were, of successive weak impulses.

Other improvements have followed rapidly, such as the soft iron ring armature of Gramme, the modifications of Wallace and Farmer, the Brush machine, and latest in point of time, perhaps, is the machine of Profs. Thomson and Houston, the patent specifications of which were published within a few days past.

Now we come, intelligently I hope, to view the machine in Mr. Edison's laboratory, which is the fountain head of his electrical power. We are at the first glance impressed by the great size of his field magnets, standing 4½ feet high, weighing, as I was told, upwards of 1,100 pounds. The cores are of wrought iron, mounted on heavy blocks of cast iron, and joined together at the top by a wrought iron yoke.

These cores are wrapped with three layers of No. 10 copper wire, insulated with cotton. The armature (which it seems to me is identical in principle, if not in construction, with Siemens) revolves in the cylindrical space between the cast iron blocks at about 500 revolutions per minute; there is the usual commutating axle with copper wire brushes for drawing off the electricity.

The field magnet is "charged" from a separate machine, and the amount of electricity poured into it depends upon the amount of electricity required in the main line. This is ingeniously and beautifully accomplished as follows:

A reflecting galvonometer is placed in the main circuit, and a small fraction of the current is continually passing into it, the amount of deflection of the needle being read by the varying position of a spot of light travelling over a scale, as in the sub-marine telegraph system. A series of resistance coils are placed in the "local circuit" between the charging machine and the field magnet of the generator proper, and a boy who watches the record on the scale cuts out or adds resistance by turning a little wheel, thereby increasing or decreasing the flow of electricity into the field magnets, thus effecting the flow on the main line just sufficiently to bring the spot of light back to its normal position. If the drain on the main conduit is increased by turning on more lights, the galvonometer indicates the fact instantly, the boy in charge pours more electricity into the field magnet, the armature develops more current, and the engine burns more coal by reason of the additional mechanical power required to be converted into additional electrical power. If we now look at the lamps we will find that they are very simple in construction. There is a small glass bulb, into the neck of which is introduced a small bulb, containing two platinum wires, hermetically sealed, and terminating inside the lamp in two little metal clips which hold the delicate horeshoe-shaped filament of carbonized paper (when I say delicate I do not mean fragile, for these little conductors are wonderfully tough and elastic, as I proved by twisting and breaking several which Mr. Edison gave me for the purpose of testing their strength). The bulb or globe is attached by the little tube to an exhausting apparatus, which is a combination of an ordinary mercury and the Sprengel pump, and the air is exhausted to the last possible degree of rarity; the end of the tube from which the bulb was blown is now sealed with the blow pipe, leaving merely a little nipple projecting, and the whole thing is hermetically closed. The platinum wires terminate outside the lamp in two metal springs, which fit into a socket attached to an ordinary gas bracket; by turning a little thumb-screw, the lamp is thrown into the electrical circuit, and the enormous resistance offered by the bad conductivity of the carbon horseshoe, combined with its great infusibility, accounts satisfactorily for the brilliant incandescence which instantly follows. The light is soft and agreeable to the eye, perfectly steady, and of a degree of whiteness that depends upon the specific resistance of each individual carbon horseshoe; a great difference being noticed in this respect between lamps hanging side by side upon the same circuit. With regard to the intensity of the light, it is claimed that each lamp is equal to 16 candles, or to give more light than an ordinary 4-foot burner. While it was not in my power to make careful comparative tests, I am not sanguine that such lights as I saw illuminating the laboratory at Menlo Park will be found equal for general illuminating purposes to an ordinarily good gas burner. The light from the best lamps is certainly very bright when you *look at it*, but the simplest test of the illuminating power is to turn your back upon the source of light and look at the space brightened by its influence. This trial I found to be an effective check upon any rising enthusiasm in regard to the illuminating value of the light as compared with a good gas burner. The difference in this respect between the ordinary gas jet and the carbon horseshoe light seems to me to be tersely expressed in the vulgar phrase, that the Edison light is "too thin," *i. e.*, while the light from the gas flame proceeds from a moderate, large quasi-solid body of luminous particles of carbon, the light from the carbon horseshoe proceeds from *a very thin filament;* it is as though you should cover a gas flame with a little screen, which would reveal merely a narrow rim of light; of course the illuminating power of the gas flame would be greatly decreased unless the incandescence of the narrow edge could be increased to a corresponding degree.

The machine of Mr. Edison generates a current of *very high electro-motive force, i. e.*, of high tension and small quantity; this permits the use of small conducting wires, and I confess I was not a little surprised to find that the whole current required to heat the incandescent lamp could be conveyed through a copper wire no thicker than a horse hair.

It appears to me that Mr. Edison, while using the same materials and similar apparatus to that of his predecessors, has in point of fact made quite a new departure in the employment of a new form of a familiar material which thus offers, *in a short circuit*, an enormous resistance (100 ohms) in conjunction with a current of sufficiently high tension to overcome that resistance with the smallest possible sacrifice of power, thus really discovering a new path through a field which had already been prospected by numerous explorors. Whether this "lead" reveal a mine or prove to be a mere *ignus fatuus* I will not venture to project.

The secretary, exhibiting one of Mr. Edison's lamps (sent to the institute by Mr. Addison B. Burk), called upon the latter for a few remarks.

Mr. Burk, in response, said that he feared he could add little to the admirably clear description of the lamp and generator given by Mr. Outerbridge. Having visited Menlo Park several times, however, he could say that Mr. Edison had certainly produced a lamp fitted, if it should have lasting qualities, to take the place of gas.

At present Mr. Edison is experimenting with lamps of different resistances to determine what resistance is best suited for his purposes. As a result, some of the lamps now exhibited give forth a light much below, the others above the candle power of a gas jet. When the light is dim, the carbon filament is of high resistance and appears as a reddish-orange line within the globe; but in lamps of low resistance, where the carbon is raised to a white heat, the source of the light disappears and the globe appears as a ball of fire.

Prof. Rogers inquired whether the speaker thought that the dimness of two lights near the station, mentioned by Mr. Outerbridge, was due to their distance from the generators.

Mr. Burk replied that he thought the distance from the generator had nothing to do with it, but that these were simply lamps of high resistance. Within a few yards of the lamps at the entrance to the park, there is an exceptionally fine lamp. In Mr. Upton's parlor some of the lamps close to the generator are no better than lamps at a distance. Mr. Burk has since ascertained that the real trouble with the distant lamps was that the current was furnished to them through conductors too small for the purpose. New lines have been laid, and the most distant lamps are now as bright as others of the same resistance elsewhere in the circuit.

In answer to other questions Mr. Burk said that many difficulties had been met with in the manufacture of the lamps. A record is kept of the life and death of each lamp, and inquest held whenever a lamp fails. Mr. Edison was recently reported to have said that 22 per cent. of the lamps failed. Mr. Burk, from his hasty examination of the records, judged that there had been fully that many failures with lamps, actually put on circuit, while there were very many lamps that never got beyond some one or other of the stages of manufacture. The causes of failure were numerous. Some of the lamps exploded or collapsed, probably because they were not strong enough to withstand the air pressure. In others, the inner bulb cracked after the lamp was lighted. Mr. Burk had watched the boys putting the platinum wires through the inner bulbs, and had noticed that sometimes when the direction of the wires did not suit them they would bend them over, thus probably putting the glass under strain. When heated under such conditions, cracking might be anticipated. This accident had occurred to the lamp shown at the Institute, in which the inner bulb was cracked in a straight line between the two platinum wires as they passed through the bulb. Some of the exploded lamps left behind them parts of the carbon horseshoe. One of these had been examined by Mr. Burk under the microscope. It did not appear very different from the carbonized paper before being made incandescent, but had a higher luster—was more metallic-looking. There was another supposed source of failure, and that was the leakage of air through the top of the bulb, where it is sealed. Mr. Edison had noted the fact that a much larger percentage of the lamps set in fixtures failed than of those hung upside down from wires. He therefore examined the seal, and saw, or thought he saw, a minute crack. He then examined some of his vacuum apparatus, similarly sealed, and found a similar supposed defect. Mr. Edison calls all difficulties "bugs," and this "bug" he got out of his lamps by adopting a new method of sealing. Conceiving that the difficulty might be in making a perfect seal in vacuum, he first sealed the tube as usual, and then admitting the air to the sealed tube, sealed it again, imprisoning a small globule of air between the first and second sealing, but obtaining clear glass around all. He thought that without this second sealing (which is done in many different ways) the crack which he found in some of his lamps might be sufficiently expanded by heat to admit a little air to the lamp and thus destroy the vacuum.

Doubts had been expressed whether the lights furnished by Edison's lamps were equal in practice to a gas jet. Mr. Burk thought there was no doubt that some of them had a higher, as some had less candle power. He had seen experiments tried in the reading of newspapers, which satisfied him on this point. There was certainly no difficulty in making the carbon give forth a light much greater than a gas jet. The whole current had been turned on one lamp (that is, all other lamps had been disconnected), and it gave forth the light of many gas jets. In Mr. Upton's parlor there is a central light hung from the ceiling that illuminates a

large room much better than the speaker had seen similar rooms in Philadelphia lighted by three gas jets. But the best evidence that the light was a fair equivalent for that of gas was to be found in the fact that sceptics visited Menlo Park and came away refusing to believe that the lamps had sufficient illuminating power to take the place of gas, and yet these same sceptics would admit, on cross-examination, that they had eaten their suppers at Mrs. Jordan's, at Menlo Park, without noticing that the dining room was lighted with two of Edison's lamps!

It is well known that the voltaic arc lamps, giving a light of say 2,000 candles, cannot take the place of gas jets having the same candle power in the aggregate. The speaker doubted whether these large lamps would replace more than one-third of their candle power in gas jets well distributed. Mr. Edison claims that, while he may lose by a division of the current in the aggregate candle power obtained from a generator, he gains on the other hand by the distribution of his smaller lights.

Prof. Elihu Thomson said:

There seems to be little doubt that an incandescent electric lamp of moderate permanency is a mechanical possibility. Whether the lamp in question answers all the requirements in this case is, of course, for the future to determine. It would seem, indeed, that a consideration of facts long in the possession of electricians and others points to the construction of a practically permanent incandescent lamp as a possibility.

The earlier lamps were short-lived; those succeeding were more lasting. The element of permanency seemed to have been gradually introduced, and the results claimed by Mr. Edison point in the same direction. Whether any new departures have yet to be taken to secure a practical enduring lamp cannot as yet be determined.

The statement has been made and repeated, that Mr. Edison was able to *turn the full current* of one of his generators on a single lamp without destroying it.

This is altogether an erroneous idea. The statement should have been that he was able to *take off* all the lamps but one from his machine, because from the resistance offered by this remaining lamp only such current could flow through it as its conducting power would allow.

The lamp was able to stand the whole electro-motive force of the machine, but not the whole current. In other words, the generator, with a single lamp in its circuit, did not *produce* more current than the lamp could easily stand.

There is, however, one phase of this subject that is vital; that is success or failure to lighting by incandescence: Does it pay? Can it compete with gas? And in this competition gas is to be regarded under its most favorable aspects, when most of the leakages are below ground and not above. Edison gets eight of his lights per horse-power; but those who have not given attention to the subject will say: but when all the improvements are made, may not sixteen per horse-power be obtained? We say no; it is impossible to obtain sixteen lights of equal power to the eight, even with the best machinery and under the most favorable conditions. The reason is that the heat energy given out in the eight lamps, as at present used, nearly equals a horse-power, and we cannot recover in the lights more power than we employ; not, indeed, more than 60 to 80 per cent. is recovered.

Eight lights per horse-power seem to be all that are obtainable without lowering the candle power of each; but then comes the question, assuming eight lights per horse-power attainable, what is their candle power? How much light do they give out? Opinions differ. Those who have seen the lights at Menlo Park must have been struck by their comparative feebleness. Their average candle power would appear to be from 8 to 10 candles. Taking the more liberal estimate, 10 candles, we get in the eight lights 80 candles, or 80 candles per horse-power. Of course incandescent lights of any desired candle power can be obtained, but an increased intensity per light means a decreased number per horse-power. Now, it is easily possible to

produce by the voltaic arc from 800 to 1,000 candles per horse-power, or over 10 times that obtainable by incandescence.

Hence it would seem that the arc must be used in the lighting of large areas in preference to incandescence, even were the economy of the latter over gas a proved fact. The cost of carbons in the arc lighting is not now of much consequence, as increased production has lowered the prices considerably. There seems, indeed, to be two fields of usefulness for electric lighting:

First. Where large areas are to be lighted or where a powerful white light is needed for special purposes the arc light is a demonstrated success and its cheapness is a recommendation.

Second. Illumination of small areas, as in house lighting, to which lighting by incandescence would seem to be peculiarly adapted, but the success of which rests on the permanency of the lamp and the economy of power consumed, both matters which have not as yet been sufficiently determined.

Prof. Robert E. Rogers had noticed at Menlo Park the absence of photometric apparatus for determining the illuminating power of the lamps. His own impression was that the light did not in any case exceed one-half that given by a gas burner consuming five feet of gas per hour.

Mr. E. Brown had an impresssion similar to that of Prof. Rogers. A new lamp which had just been put in operation did not equal a 5-foot burner; many of the lamps were much below that standard. While taking supper he did not notice for some time that the illumination was from electric lamps, one being placed at each end of the chandelier, showing that the light resembled closely that from gas or oil.

Mr. Smethurst was of opinion that the light had a greater illuminating power than an ordinary gas light, and thought that reading by it was not a reliable test. (Notes following the foregoing.)

1. In 1845 an American inventor named Starr took out in England through his agent, King, a patent (No.

10,919, dated November 4) for producing light by electricity, which contained, among other matter, the following description: "The invention has for its basis the use of metallic conductors or of continuous carbons, heated to whiteness by the passage of the electric current. The best metal for this purpose is platinum, the best carbon is retort carbon. When carbon is employed it is useful on account of its affinity for oxygen at high temperatures to cover it from air and moisture." Here follows a description of the figure, which shows a thin rod or filament of carbon enclosed in a glass vessel. The patent then continues:

"A vacuum is previously established in the bell, and the apparatus veritably forms a barometer, with one of the poles of the battery in communication with the column of mercury and the other with the conductor D." The conductor D is represented as sealed directly into the glass globe or bell, and the reference to the barometer shows clearly that the vacuum produced was what is known as the Torricellian vacuum, which, as far as the absolute exclusion of air or gas, is equal to anything otherwise attainable, and fully equivalent for practical purposes to what Mr. Edison produces in his lamps. If, therefore, these lamps are of any practical use so also would lamps be if made according to the King patent, which is, of course, open to all the world.

King, or rather, Starr was followed by various inventors and patentees who modified or improved the details of his general plan, as Staite & Petrie, Loelyguyne Konn, Bouliguine, Fontaine, and more recently, Sawyer. None of these have ever reached any permanent success in the practical application of their systems; how far this has been the result of unfavorable circumstances, and how far it has come from radical defects in their systems, cannot as yet be determined, but it is evident that the ground has been thoroughly planted with devices and with patents from which will spring a fruitful crop of litigation should any success on the part of one or other of the closely allied methods make it worth while to contest the validity of rival claims.—*Sanitary Review.*

2. At a meeting of the French Academy, held March 1, 1858, there was received from M. Jobart a communication in which he speaks as follows:

"I hasten to announce to the Academy the important discovery of the dividing of an electric current for lighting purposes. This current, from a single source, traverses as many wires as may be desired, and gives a series of light ranging from a night lamp to a lighthouse lamp.

"The luminous arc between the carbons produces, as is well known, a very intense, flickering and costly light. M. de Changy, who is a chemist, mechanician and physicist, is thoroughly conversant with the latest discoveries, and has just solved the problem of dividing the electric light.

"In his laboratory, where he has worked alone for the past six years, I saw a battery of twelve Bunsen elements producing a constant luminous arc between two carbons, in a regulator of his own invention, this regulator being the most simple and perfect I have ever seen. A dozen small miner's lamps were also in the circuit, and he could, at pleasure, light or extinguish either one or the other, or all together, without diminishing or increasing the intensity of the light through the extinction of the neighboring lamps. The lamps, which are enclosed in hermetically sealed glass tubes, are intended for the lighting of mines in which there is fire-damp, and for the street lamps, which would, by this system, be all lighted or put out at the same time on the circuits being opened or closed. The light is as white and pure as Gillert's gas, with which it has one point in common, namely, its production by incandescence of platinum. The gas pipes are replaced by simple wires, and no explosions, bad smells or fires can take place.

"The trials that have hitherto been made with the object of producing electric light by means of heated platinum have failed on account of the melting of the wires. This difficulty has been overcome by M. de Changy's dividing regulator. The cost of the light is estimated to be half that of gas. A lamp placed at the masthead of a ship would form a permanent signal for about six months without the necessity of changing the platinum. With several such lights, placed in tubes of colored glass, it would be easy to telegraph by night, as they could be extinguished and relighted rapidly from the deck.

"For lighthouse purpos s considerable amplitude can be given to the light. I also saw a lamp so arranged in a thick glass globe that it could be immersed to considerable depths without being extinguished by any movement. This lamp has already been used in the taking of fish, which were attracted towards the light.

"The above slight description will suffice to show to what a variety of applications this discovery can be put. The communication which I have had the honor of laying before the Academy is founded upon no illusion; a lamp was, to my astonishment, lit in the hollow of my hand, and remained alight after I had put it in my pocket with my handkerchief over it."

Complainant's Exhibit Barker's Lecture. S. M. H., Exr.

[*New York Herald, Thursday, March 25, 1880.*]

Edison's Electric Light.

Lecture by Professor Barker before the Franklin Scientific Society. An Unequalified Indorsement of The Edison Light. Cheaper Than Gas At Sixty Cents A Thousand Feet. A Tribute To The Great Inventor.

(By Telegraph To The Herald.)

Philadelphia, March 24, 1880.

Professor George F. Barker, M. D., Professor of Physics of the University of Pennsylvania, lectured before the Franklin Scientific Society to-night on the electric light. Great importance attached to the lecturer because of his recent return from Menlo Park, where he had been engaged, with Professors Young, Brackett and Rowland, in making an exhaustive series of experiments with the Edison electric Light. He had repeatedly declined to state the result of his visit, declaring that not until he had thoroughly tabulated all the data in his possession would he make the result of his visit public.

After introducing the general subject of electric lighting Professor Barker directed his remarks solely to Edison's light in its latest form.

First, as to the new generator, which he pronounced a perfect success. "I know all other generators," said the lecturer, "and Edison's is best of all. With a resistance of only one ohm he gets 164 units of energy. The theory upon which it is built is exactly the reverse of previous inventors of electrical generators. Edison aims at low resistance, but high motive force." The lecturer then took up the lamp itself. "Careful experiments convince me," said he, "that the vacuum in the lamp is now within one four-millionths of a perfect exhaustion. The strictures regarding the exhaustion are merely absurd. A long series of experiments with various kinds of fibres, such as Southern moss, bass wood, palmetto, Mexican hemp, jute, cocoanut, palm and manila demonstrates that manila fibre is much tougher and better adapted for 'horseshoes' in the lamp than any other material." The Professor illustrated his remarks at this point by taking a bundle of charred manilla "horseshoes," straightening them and actually tying a knot in them. The greater part of the discourse was delivered in the light furnished by the several incandescent lamps distributed about the hall. This decision, after all the tests in favor of manilla fibre, forever settled in Professor Barker's opinion, the practicability of the light. It disposed of the platinum problem and left only one question of economy to be considered. "I now propose to show that we get our light energy (for there is nothing bought or sold in this world that does not represent energy) cheaper through electricity than gas. To calculate with exactness the comparative merits of electricity over gas, we must reduce it to heat. This is done by burning one of these lamps immersed in water. This is called the test by the calorimeter. To this end when at Menlo Park a few days ago I chose one pair of lamps of low resistance, one pair of high resistance, one pair with the smallest horseshoes yet used, all these of paper, and one lamp (No. 817) with the manilla fibre connection." The lecturer here read the tabular results of his investigation. "Now," said he, resuming, "I shall prove the cheapness of this light by a demonstration on the blackboard. The gas engine that drives the Gramme generator below requires twenty cubic feet of gas per hour to produce one horse power. Ten lights of sixteen-candle power are produced for each horse power; therefore, we get 160 candles from twenty cubic feet of gas. On the other hand, a five-foot burner equals sixteen-candle power, giving us only sixty-four candles from the consumption of twenty cubic feet of gas as light. It is cheaper, therefore, to run an engine for an electrical generator with gas than to consume it for light. In other words, it contains far more heat energy than light. To state this

proposition more scientifically, one pound of coal gas will give us light equal to seventy-five candles. This pound, if burned in the calorimeter, that is, under water, will equal 20,000 heat units, equal to 16,000,000 foot pounds, equal to 250,000 foot pounds per minute. One candle, therefore, requires more than 3,300 foot power per second. Again, mechanically the cost of running an engine may be very literally set down at three cents per horse power per hour. This applied to driving Edison's generator gives us ten lights of sixteen candles each, that is, ten lights per three cents, or three-tenths of one cent for each light of sixteen-candle power. Now, look at the contrast. Gas, we will say, is $2 per thousand. Five cubic feet of gas costs at the rate of one cent; that is to say, we get three electric lamps, such as you see before you, for the same cost as one five-foot gas burner light. In language still more simple, I can positively say, after the most careful computation, into which I cannot go on this occasion, that until gas can be furnished for sixty cents per 1,000 cubic feet the electric light is cheaper."

The lecturer closed with a tribute of respect and admiration for Mr. Edison. A few days ago, when he assured the Wizard that calculation convinced him that ninety-eight per cent. of the energy was secured by his new generator, Edison exclaimed, "If that be so, man is absolute master of nature. Ninety-eight per cent. of nature means the control of the forces of the world. Electricity is light and heat. We have only to place our engines at the coal mines and transmit the heat and light wherever it is needed." The lecture was listened to by a very large audience.

Complainant's Exhibit "Sawyer's Tribune Letter of March 26, 1880," January 22, 1890. S. M. H., Exr.

[*New York Tribune, March 26, 1880.*]

W. E. Sawyer on Edison's Light—Some of the Incredible Claims of Professor Barker Denied.

To the Editor of the "Tribune":

Sir—It may have been a wise move on the part of the managers of the Edison electric light to organize a Board to report upon its merits. The public not being supposed to know enough to judge for itself, a Board is in order.

Professor George F. Barker, of the University of Pennsylvania (if the newspaper accounts are correct, and I suppose they are) is the head of the board. In a lecture delivered in Philadelphia last evening the Professor made some erroneous statements. He said: "I know all other generators, and Edison's is best of all." To this I would reply that Mr. Edison's generator is inferior to several others in practical use to-day.

Professor Barker said: "Ninety-eight per cent. of the energy was secured by his (Edison's) new generator." I positively assert that Mr. Edison's generator does not develop 45 per cent. in electricity of the power applied to it.

Professor Barker is reported to have tied a knot in a bundle of carbonized manilla horseshoes. This is physically impossible. The professor may have taken horseshoes charred only upon the surface and tied a knot with them, but not with carbonized manilla or any other material. Carbon, however fibrous, is as brittle as glass.

Professor Barker said that with the Edison lamp, "ten lights of 16 candle power are produced for each horse power." I assert that Mr. Edison cannot obtain more than two lights of 12 candle power each per horse power. Mr. Edison does not get more than 24 candle light per horse power—not 160, as Professor Barker asserts. Mr. Edison has not yet learned that the greater the resistance of a lamp the greater the power required to operate it.

Possibly Professor Barker is mistaken in his calculations, and may in future correct them. If so, his real friends will be pleased. If not, he must expect criticism; and I am prepared to meet any allegation the moment it is reduced to figures.

Respectfully,

W. E. Sawyer.

New York, March 25, 1880.

Complainant's Exhibit Rowland and Barker Paper. S. M. H., Exr.

From the American Journal of Science, Vol. XIX. April, 1880.

(Published in advance in the New York "Herald" for March 27, 1880.)

On the Efficiency of Edison's Electric Light.

By Professor H. A. Rowland of the Johns Hopkins University, and Professor George F. Barker, of the University of Pennsylvania.

The great interest which is now being felt throughout the civilized world in the success of the various attempts to light houses by electricity, together with the contradictory statements made with respect to Mr. Edison's method, have induced us to attempt a brief examination of the efficiency of his light. We deemed this the more important because most of the information on the subject has not been given to the public in a trustworthy form. We have endeavored to make a brief but conclusive test of the efficiency of the light, that is, the amount of light which could be obtained from one horse-power of work given out by the steam engine. For if the light be economical, the minor points, such as making the carbon strips last, can undoubtedly be put into practical shape.

Three methods of testing the efficiency presented themselves to us. The first was by means of measuring the horse-power required to drive the machine, together with the number of lights which it would give. But the dynamometer was not in very good working order, and it was difficult to determine the number of lights and their photometric power, as they were scattered throughout a long distance, and so this method was abandoned. Another method was by measuring

the resistance of and amount of current passing through, a single lamp. But the instruments available for this purpose were very rough, and so this method was abandoned for the third one. This method consisted in putting the lamp under water and observing the total amount of heat generated in the water per minute. For this purpose, a calorimeter, holding about 1¼ kil. of water, was made out of very thin copper, the lamp was held firmly in the center, so that a stirrer could work around it. The temperature was noted on a delicate Baudin thermometer graduated to 0°. 1 C.

As the experiment was only meant to give a rough idea of the efficiency within two or three per cent., no correction was made for radiation, but the error was avoided as much as possible by having the mean temperature of the calorimeter as near that of the air as possible, and the rise of temperature small. The error would then be much less than one per cent. A small portion of the light escaped through the apertures in the cover, but the amount of energy must have been very minute.

In order to obtain the amount of light and eliminate all changes of the engine and machine, two lamps of nearly equal power were generally used, one being in the calorimeter while the other was being measured. They were then reversed and the mean of the results taken. The apparatus for measuring the light was one of the ordinary Bunsen instruments used for determining gas-lights, with a single candle at ten inches distance. The candles used were the ordinary standards burning 120 grains per hour. They were weighed before and after each experiment, but as the amount burned did not vary more than one p. c. from 120 grains per hour, no correction was made.

As the strips of carbonized paper were flat, very much more light was given out in a direction perpendicular to the surface than in the plane of the edge. Two observations were taken of the photometric power, one in a direction perpendicular to the paper, and the other in the direction of the edge, and we are required to obtain the average light from these. If L is the photometric power perpendicular to the paper, and l that of the edge, then the average λ will evidently be very nearly

$$\lambda = L\int_{\frac{1}{2}\pi}^{0} \cos a \sin a \, da + l\int_{\frac{1}{2}\pi}^{0} \sin^2 a \, da$$

$$\lambda = \tfrac{1}{2}L + \frac{\pi}{4} l$$

In the paper lamps we found $l = \frac{1}{3}L$ nearly; hence $\lambda = \frac{3}{4}L$ nearly.

The lamps used were as follows :

No.	Kind of carbon.	Size of carbon.	Approximate resistance when cold.
580	paper	large	147 ohms.
201	"	"	147 "
850	"	small	170 "
809	"	"	154 "
817	fiber	large	87 "

The capacity of the calorimeter was obtained by adding to the capacity of the water the copper of the calorimeter and the glass of the lamp and thermometer. The calorimeter and cover weighed 0.103 kil. and the lamps about 0.035 kil.

First experiment, No. 201 in calorimeter and No. 580 in photometer; capacity of calorimeter =1.153+.009+.007=1.169 kil. The temperature rose from 18°.28 C. to 23°.11 C. in five minutes, or 1°.75 F. in one minute. Taking the mechanical equivalent as 755., which is about right for the degrees of this thermometer, this corresponds to an expenditure of 3,486 foot pounds per minute. The photometric power of No. 580 was 17.5 candles maximum, or 13.1 mean, λ.

When the lamps were reversed, the result was 3,540 foot pounds for No. 580, and a power of 13.5 or 10.1 candles mean.

The mean of these two gives, therefore, a power of 3,513 foot pounds per minute for 11.6 candles, or 109.0 candles to the horse-power.

To test the change of efficiency when the temperature varied, we tried another experiment with the same pair of lamps, and also used some where the radiating area was smaller, and, consequently, the temperature had to be higher to give out an equal light.

We combine the results in the following table, having calculated the number of candles per indicated horse-power by taking 70 per cent. of the calculated value, thus allowing about 30 per cent. for the friction of the engine, and the loss of energy in the magneto-electric machine, heating of wires, etc. As Mr. Edison's machine is undoubtedly one of the most efficient now made, it is believed that this estimate will be found practically correct. The experiment on No. 817 was made by observing the photometric power before and after the calorimeter experiment, as two equal lamps could not be found. As the fiber was round, it gave a nearly equal light in all directions, as was found by experiment.

Lamps used in. Calorimeter.	Photometer.	Photometric power measured perpendicular to paper, L.	Average, λ	Capacity of Calorimeter in pounds.	Rise of temperature in degrees F.	Energy per minute in foot pounds.	Mean number of candles per horse-power of electricity.	Mean number gas jets of 16 candles each per horse-power of electricity.	Mean number of gas jets per indicated horse-power.
201	580	17.5	13.1	2.57	1°.75	3486.	109.0	6.8	4.8
580	201	13.5	10.1	2.82	1°.62	3540.			
580	201	38.5	28.9	2.74	2°.41	5181.	201.3	12.8	8.9
201	580	41.6	33.5	2.76	2°.29	4898.			
850	809	19.0	14.3	2.81	1°.11	2183.	133.4	8.3	5.8
809	850	12.2	9.2	2.79	1°.54	3330.			
817			17.2	2.73	1°.28	2708.	209.6	13.1	9.2

The increased efficiency, with rise of temperature, is clearly shown by the table, and there is no reason, provided the carbons can be made to stand, why the number of candles per horse-power might not be greatly increased, seeing that the amount which can be obtained from the arc is from 1,000 to 1,500 candles per horse-power. Provided the lamp can be made either cheap enough or durable enough, there is no reasonable doubt of the practical success of the light, but this point will evidently require much further experiment before the light can be pronounced practicable.

In conclusion, we must thank Mr. Edison for placing his entire establishment at our disposal, in order that we might form a just and unbiassed estimate of the economy of his light.

Complainant's Exhibit "Dr. Morton's Published Test of an Edison Horseshoe Lamp," Mar. 8, 1890. S. M. H., Exr.

"The Telegraph Journal and Electrical Review."

Vol. VIII., pp. 151, 152. London May 1, 1880.

SOME ELECTRICAL MEASUREMENTS OF ONE OF MR. EDISON'S HORSESHOE LAMPS.

By Henry Morton, Ph. D., Alfred M. Mayer, Ph. D., and B. F. Thomas, A. M., at the Stevens Institute of Technology:

Much has been written and said within the last few months on the subject of Mr. Edison's new horseshoe lamps, and with all the writing and saying there has been wonderfully little produced in the way of precise and reliable statement concerning the simple primary facts, a knowledge of which would give the means of estimating both the scientific and commerical status of this widely discussed invention.

It was, therefore, with great pleasure that the present writers found themselves, through the kindness of the "Scientific American," placed in possession of one of these horseshoe lamps of recent construction.

To satisfy themselves as to the real facts of the case, they soon made a series of careful measurements and determinations, and as the results of these are likely to interest others, they now put them in print for general benefit.

A further examination of other lamps would have been made at the same time had opportunity offered; but as a communication on this subject addressed to Mr. Edison did not evoke a reply, they are obliged to content themselves with the one lamp as a subject of experiment.

They would, however, here remark, that the behaviour of this lamp, under the tests, and the agreement of its results with information otherwise obtained, convince them that it is at least a fair specimen of the lamps of this form so far produced at Menlo Park.

The first object, on receiving the lamp, was to determine roughly what amount and character of electric current would be needed to operate it efficiently. With this view a number of cells of a small Grove's battery were set up, having each an active zinc surface of twenty square inches and a platinum surface of eighteen square inches.

The lamp being placed in the situation usually occupied by the standard burner in a Sugg's photometer, the battery was, cell by cell, thrown into circuit.

When ten cells had been introduced the horseshoe showed a dull red, with fifteen cells a bright red, with thirty-four cells the light of 1 candle was given, with forty cells the light of $4\frac{1}{2}$ candles, and with forty-five cells the light of 9 1-5 candles, and with forty-eight cells 16 candles.

Having thus determined what amount of electric current would be required for experiments, arrangements were made to measure accurately the resistance of horseshoe while in actual use and emitting different amounts of light. The resistence of this carbon thread at the ordinary temperature had been already determined as 123 ohms in the usual way, but it was presumed, as had been shown by Matthiessen (Phil. Mag., XVI., 1858, pp. 220, 221), that this resistance would diminish with rise of temperature.

To measure the resistance under these circumstances the apparatus was arranged as follows: The current from the battery was divided into two branches, which traversed in opposite directions, the two equal coils of a differential galvanometer. One branch then traversed the lamp, while the other passed through a set of adjustable resistances composed of German silver wires stretched in the free air of the laboratory, to avoid heating. (Careful tests of these resistances showed that no sensible heating occurred under these circumstances).

Matters being thus arranged the resistances were adjusted until the galvanometer showed no deflection

when the candle power of the lamp was taken repeatedly in the photometer, and the amount of resistance was noted.

These measurements were several times repeated, shifting the coils of the galvanometer and reversing the direction of the current.

The results so obtained were as follows:

Resistances.		Condition of Loop.
123	ohms.	Cold.
94	"	Orange light.
83.7	"	$\frac{9}{10}$ Candle.
79.8	"	5 "
75	"	18 "

The photomeric measurement was in all these cases taken with the carbon loop at right angles to the axis of the photometer, which was, of course, much in favor of the electric lamp. On turning the lamp round so as to bring the carbon loop with its plane parallel with the axis of the photometer, *i. e.*, the edge of the loop turned toward the photometer disc, the light was greatly diminished, so that it was reduced to almost one-third of what it was with the loop sideways to the photometer disc.

Having thus determined the resistance of the lamp when in actual use, it was next desirable to measure the quantity of the current flowing under the same conditions.

To do this the current from fifty cells of battery was passed through a tangent galvanometer as a mere check or indicator of variations, and then through a copper voltameter, *i. e.*, a jar containing solution of cupric sulphates with copper electrodes immersed, and then through the lamp, placed in the photometer.

Under these conditions it was found that during an hour the light gradually varied from about 16 candles at the begining to about 14 candles at the end, making an average of about 15 candles, measured with side of loop toward disc.

The galvanometer during this time only showed a fall of half a degree in the deflection of the needle.

Carefully drying and weighing the copper electrodes, it was found that one had lost 1.0624 grammes.

Now, it is well known that a current of one Weber takes up 0.00326 gramme of copper per second, which would make 1.1736 grammes in an hour; therefore the current in the present case must have been on the average $\frac{1.0624}{1.1736} = 0.906$ Weber, or a little less than one weber.

Having thus obtained the resistance of the lamp when emitting a light of 15 candles, namely, 76 ohms, and the amount of current passing under the same conditions, namely, 0.905 Weber, we have all the experimental data required for the determination of the energy transformed or expended in the lamp, expressed in foot-pounds. For this we multiply together the square of the current, the resistance, the constant 0.737335 (which expresses the fraction of a foot-pound involved in a current of one Weber traversing a resistance of one ohm for one second), and the number of seconds in a minute. Thus, in the present case, we have $0.905^2 = 0.8125$, and $0.8125 \times 76 \times 0.737335 \times 60 = 2753.76$ foot-pounds.

Dividing these foot-pounds per minute by the number of foot pounds per minute in a horse-power, that is, 33,000, we have 0.08, that is, about eight one-hundredths or one twelfth of a horse-power as the energy expended in each lamp.

It would thus appear that with such lamps as this, one horse-power of energy in the current would operate 12 lamps of the same resistance with an average candle power of 10 candles each or 120 candles in the aggregate.

Assuming that a Siemens or Brush machine were employed to generate the electric current, such a current would be obtained, as has been shown by numerous experiments, with a loss of about 40 per cent. of the mechanical energy applied to the driving pulley of the machine. To operate these 12 lamps, therefore, we should have to apply more than one horse-power to

the pulley of the machine, so that when this loss in transformation had been encountered there should be one horse-power of electric energy produced. This would call for 1⅔ horse-power applied to the pulley of the dynamo-electric machine by the steam engine.

To produce one horse-power in a steam engine of the best construction about 3 lbs. of coal per hour must be burned, and therefore for 1⅔ horse-power 5 lbs. of coal must be burned.

On the other hand 1 lb. of gas coal will produce five cubic feet of gas, and will leave, besides, a large part of its weight in coke, to say nothing of other "residuals" which will represent practically about the difference in value between "steam-making" and "gas making coal," so that it will not be unfair to take 5 lbs. of gas coal as the equivalent of 5 lbs. of steam coal.

These 5 lbs. of gas coal will then yield 25 cubic feet of gas, which, if burned in five gas burners of the best construction, will give from 20 to 22 candles each, or 100 to 110 candles in the aggregate.

We have, then, the twelve Edison lamps producing 120 candles and the five gas burners producing 100 to 110 candles, with an equivalent expenditure of fuel.

If each apparatus and system could be worked with equal facility and enconomy this would, of course, show something in favor of the electric light, but when, in fact, everything in this regard is against the electric light, which demands vastly more machinery, and that of a more delicate kind, requires more skillful management, shows more liability to disarrangement and waste, and presents an utter lack of the storage capacity which secures such a vast efficiency, convenience and economy in gas, then we see that this relatively trifling economy disappears or ceases to have any controlling importance in the practical relations of the subject.—*Scientific American.*

NOTE.—This article is followed by corrections and explanations published in the same journal for May 15, 1880, on page 178, which read as follows:

EDISON'S HORSESHOE LAMPS.—Messrs. Henry Morton,

A. M. Mayer, and B. F. Thomas, who recently published in the *Scientific American* an account of some electrical measurements of one Mr. Edison's horseshoe lamps, and which we reprinted in our last issue, have since published the following additions and corrections to their past article:

"In reading our first article in print we notice some errors which require correction, and some points calling for a more full explanation.

"It was said in the article that the loss of weight in one of the electrodes was 1.0624 grammes.

"This was, in fact, the amount gained by the cathode, the loss of the anode being a trifle greater. The gain of weight was, of course, what it was intended to take, so that the error was only in the expression, and not in the process or result.

"In the next place, in the foot note at the end of the same column, it is simply stated that the average of the maximum and minimum lights in azimuths at right angles and in the plane of the loop was taken as the average luminous power of the lamp. Our reason for this, however, was not mentioned, but was, in fact, that we found by measuring the light at every azimuth varying by ten degrees between 0° and 180°, that this was approximately the true expression for the total amount of light emitted. We see from the article of Profs. Rowland and Barker, in the *American Journal of Science*, that they, assuming certain conditions and discussing the same in a mathematical manner, have reached a different result; but, as the experiment shows this result not to be attained in fact, it is evident that the assumptions on which the mathematical reasoning is based do not include all the conditions present in the experiment.

"Two other sets of experiments, made since those given in our paper of April 17, in which the candle-power of the loop was in its best position, 17.6 and 19.8 candles, corresponding to averages of 11.7 and 13.2 candles respectively, showed a consumption of energy of 0.104 and 0.109 horse-power per lamp, or 9.6 and

9.1 lamps per horse-power. This would give 112 candles and 120 candles respectively per horse-power of electric energy consumed or transformed in the lamp. These results certainly agree very closely with each other and with our former determinations."

Complainant's Exhibit Brackett-Young Test of Edison Dynamo. S. M. H., Exr.

[*From the American Journal of Science, Vol. XIX, June, 1880.*]

(Published in advance in the "Scientific American" for May 15, 1880.)

ART. LXV.—*Notes of Experiments upon Mr. Edison's Dynamometer, Dynamo-machine and Lamp:* by Professors C. F. BRACKETT and C. A. YOUNG of Princeton, N. J.

DURING the experiments of Professors Rowland and Barker, the results of which appeared in the April number of this Journal, one of us (Professors Brackett) happened to be present; and he was requested by Mr. Edison to make an independent study of the subject under investigation.

Accordingly, we visited Menlo Park on March 19th and again on April 3d. On our first visit, we confined ourselves mainly to a study of the resistance, luminosity and efficiency of the lamp, making only a single test of the efficiency of the machine. On the second visit, we gave our attention to the dynamometer and the machine.

It is obvious that the work attempted in the time at our dispossal was considerable; and, in consequence, no extreme accuracy is claimed for our results—though we believe them to be substantially correct—that is to say, within one or two per cent.

We first made a comparison of Mr. Edison's dynamometer with the well known Prony, the latter being driven through the former precisely as the dynamo-machine was, during the trials made to determine its efficiency. We found that the Prony registered 93.2 per-cent. of the power transmitted by the Edison. This result we consider quite reliable, the 6.8 loss being reasonably accounted for by friction of our counter-

shaft journals and the slip of the belt intervening between the instrument.

To determine the efficiency of the dynamo-machine, we made three different tests. In all of them the power expended in driving the revolving armature was measured directly by the Edison dynamometer. The small additional amount spent in maintaining the field of force was calculated from the measured resistance of the magnet coils (1.47 ohms) and the difference of electric potential between the terminals of the coils, measured by a high resistance galvanometer (Thomson). It was assumed in this calculation that the machine which furnishes this current was of about the same efficiency as the one experimented on, it being of similar construction. The formula is

$$1.25 \times 44.25 \text{ ft. lbs.} \times \frac{V^2}{r} \times t,$$

where t is the duration of the experiment in minutes. V is the difference of potential in volts; r is the resistance or the coil 1.47 ohms. 44.25 is the number of foot lbs. of work done in one minute by an electromotive force of one volt driving a current through one ohm; and finally 1.25 is a factor embodying the assumption that the efficiency of the machine, producing the magnetizing current, is 80 per cent. The amount of this expenditure is trifling, not exceeding three per cent. of the work used in driving the armature, but its neglect might lead to misapprehension.

On March 19th the current produced was measured by the electrolytic method. We employed copper electrodes presenting opposed surfaces of about one square foot each, and placed about one inch apart in a solution of cupric sulphate. We also measured the resistance of the circuit by the bridge method both at the beginning and end of the experiment so as to take account of heating. For a check, we also measured the difference of potential between the terminals of the machine.

On April 3d we had recourse to the calorimeter, employing a resistance coil immersed in about 175 lbs. of water, the resistance of the coil being such that the work done elsewhere in the circuit could be calculated and allowed for as a small fraction of that directly measured. The difference of potential between the terminals was also measured for a check, as on March 19th. The resistance of the armature was 0.14 of an ohm; that of the rest of the circuit was made to vary in the different experiments, from 1.9 to 3.2 ohms.

We shall use the expression *available energy* to denote the energy developed in that part of the circuit which is outside of the machine. The total energy of course includes that which is uselessly spent in heating the coils of the armature itself, a very small portion in this form of machine. Our results are as follows.

On March 19th the experiment lasted five minutes. We found:

Energy expended in driving armature	971,500	ft. lbs.
Energy expended on field of force	16,400	"
Total	987,900	"

The current calculated from the amount of copper deposited was 34,335 webers: the mean resistance of the circuit was 3.12 ohms, or, excluding the armature, 2.98 ohms. The electromotive force, indicated by the galvanometer, was 102.36 volts.

From these data we calculate:

Total energy realized in the current	814,400	ft. lbs.
Available energy (excluding armature)	777,200	"

Hence the total efficiency is 82.3 per cent., and the available efficiency 78.7 per cent.

On April 3d the first test lasted 13^m 50^s, and we found—

Energy expended in driving armature	2,844,600	ft. lbs
Energy expended on field	19,634	"
Total	2,864,234	"

The total weight of calorimeter and its contents was

197.5 lbs. Making the proper reduction for weight, metals, thermometer, etc., we find the heat capacity of the whole to be 172.77 water lbs.

The rise in temperature, measured by a thermometer, easily read to $\frac{1}{20}$ of a degree, was 16.7° F.; and the precaution was taken to terminate the experiment when the temperature had risen as much above that of the air (71.2°) as it was below at the beginning thus obviating the necessity of a radiation correction.

The resistance of the coil in the calorimeter was 1.72 ohms; that of the leading wires was only about 0·006, or $\frac{1}{300}$ of the preceding. Hence assuming 772 ft. lbs. as the mechanical equivalent of heat we have—

Energy developed in calorimeter	2,227,500	ft. lbs.
Energy developed in leading wires	7,425	"
Energy developed in armature	183,670	"

That is to say:

Total energy realized	2,418,600	"
Available energy realized	2,234,925	"

which makes the total efficiency 84.6 per cent. and the available efficiency 78.2 per cent.

During the experiment the electromotive force of the current by which the field magnets were maintained was only 6.25 volts, consequently the machine was not giving nearly its maximum current—the energy expended being about 6.25 horse-power and the current about 46 webers.

During the next test, which continued nine minutes, the electromotive force of the field coils were maintained at 14.9 volts, and the current produced was 57.5 webers—consuming 9.5 horse-power.

The calorimeter was refilled with fresh water; and proceeding as before we found—

Energy measured by dynamometer	2,827,550	ft. lbs.
Energy expended on field	72,180	"
Total	2,899,730	"

Energy realized in calorimeter	2,259,700	ft. lbs.
Energy realized in leading wire	7,532	"
Energy realized in armature	183,930	"
Total	2,451,162	"
Available	2,267,238	"

Total efficiency	84.5 per cent.
Available efficiency	78.2 "

These results were confirmed by the reading of the high resistance galvanometer.

Tabulating our results they stand thus:

	Total efficiency.	Available efficiency.
1st	82.3 per ct.	78.7 per ct.
2d	84.6 "	78.2 "
3d	84.6 "	78.2 "
Mean	83.8 "	78.4 "

If we assume that the indications of the Prony dynamometer are reliable and that the loss in transmitting power between the Edison dynamometer and the arbor of the amature was only the same as the loss between the two dynamometers, the above numbers will have to be increased in the ratio of 100 to 93·2, and we shall have—

Total efficiency	89.9 per cent.
Available efficiency	84.1 "

The figures we believe fairly represent the performance of the machine in its present condition.

As points of excellence in the construction of this machine, we may mention the employment of large masses of iron for the field magnets; the breaking up of the armature core into thin plates, thus avoiding the expenditure of much useless work; and finally, the almost entire absence of sparks at the commutator brushes, even when the machine is doing its maximum of duty.

Test of the Lamp.

The photometric tests were made by the well-known method of Bunsen. The lamp, which was furnished us, was No. 853, one of the old pattern with carbon of charred paper, which had been used by Professors Rowland and Barker.

An arrangement was adopted by which the current employed, the difference of potential of the lamp wires and the resistance of the lamp could be measured, continuously, during the photometric observations. The current was measured by the deposition of copper in an electrolytic cell. The resistance was found by making the lamp one arm of a Wheatstone's bridge, suitably proportioned. The difference of potential was measured by a Thomson's high resistance galvanometer connected with the lamp terminals.

During the first test, which lasted twenty minutes, the mean photometric intensity "broadside on" was 13.8 candles. Calculation shows the mean illumination to be about 73 per cent. of the maximum, hence, the mean illumination was about 10.1 candles.

The resistance of the lamp while shining was found to be 99.6 ohms; and the difference of potentials at its terminals was 74.33 volts, (producing a current of 0.75 weber); hence the lamp was consuming 0.075 of a horse power. Or, adopting our previous result for the available efficiency of the dynamo-machine, we find that one horse-power *measured at the Edison dynamometer* would maintain a number of lamps represented by the formula $\frac{78.4}{0.075 \times 100} = 10.5$, nearly.

During the second test, which lasted thirty minutes, the mean candle power of the lamp was 10.7 candles, calculated as before.

The resistance was	99.7 ohms.
The difference of potential	76.5 volts.
The current	0.76 weber.

Accordingly the lamp was consuming 0.077 of a horse-power—or one horse-power applied as before, would maintain 10.2 lamps at this candle power.

Taking the mean of these results we find that one horse-power *applied at the dynamometer* would produce in a lamp of this pattern and dimensions a light of 107 candles; or about 137 candles if we estimate the energy actually developed in the lamp in terms of horse-power.

Mr. Edison kindly put everything we required at our disposal, and himself, as well as Mr. Upton and his other assistants, aided us in every possible way.

Complainant's Exhibit "Sawyer's Herald Letter of August 12, 1880." Jany. 22, 1890. S. M. H., Exr.

[*New York Herald, August 12, 1880.*]

EDISON'S LIGHT AND LOCOMOTIVE.—PROFESSOR SAWYER GIVES A FREE EXPRESSION OF OPINION ON THE MATTER AND PROPOSES SOME SCIENTIFIC CONUNDRUMS.

NEW YORK, August 10, 1880.

TO THE EDITOR OF THE HERALD:

I note your article in this morning's "Herald" explaining why Professor Edison has made haste so slowly with his 233 inventions, and have also remarked other statements from Menlo Park concerning the same. Whatever criticism may be passed upon what I have said, or may say, or the motives thereof, my purpose has been and is, solely to correct any public misapprehension regarding this subject, for there is nothing to-day made so deceptive as this very subject of electricity, and I cannot appreciate the design of any one in exaggerating its importance or the results obtained or to be obtained from it. There is no more reason why it should be misconstrued than there is for the misconstruction of any other force. It is no mystery, except as all other forces are mysteries. It is as easily weighed, and, so to speak, divided as any other force. The attempt to represent it as a force more subtle and incomprehensible than others is a mistake. The transmission of light and heat, the force of attraction which holds the world in its track at a distance of 95,000,000 miles from the sun, the attraction of cohesion of particles, whereby all matter is made manifest, &c., these mysteries excite no comment in the minds of many who raise electricity to the dignity of exceptional subtlety. All other forces are equally subtle, as any one will find who essays their explanation. The supposed to be most commonly understood of all sciences—that of steam engineering—has, after a century of the work of the best genius and the expenditure of untold wealth, resulted in what? In the recovery from a pound of coal ten per cent of the energy stored up in it. Yet an electrical generator is said to be fashioned in an hour that yields 90 to 100 per cent of the power applied to it, and the electricity thus generated is as readily reconverted into power at an equally high percentage. Men who do not know an ohm from a microfarad make an experiment and settle the whole question by their certificate, with about the same accuracy as a physician would make a suit of clothes or the tailor treat his patient. Is it not about time that this sort of business should cease? or, at least, that those really familiar with the subject should tell the truth about it? When electricity shall be more generally understood, those who lend their names to any deception will be most thoroughly understood. There is one thing that never succeeded like success, and that is successful deception. I do not mean to charge that there is any deception at Menlo Park. That would certainly be unwise. But what I do wish to state, and am prepared to substantiate, is included in the following:

Professor Edison claims that he can supply his electric lamps at thirty-five cents apiece. Perhaps this is so; undoubtedly Professor Edison is able to give them away. But, nevertheless, his lamps to-day cost him ten times that amount, and when it was announced (without authority, of course) that their cost was twenty-five cents apiece it was really not less than $5 or $6 for each and every working lamp. It is stated that the average power of the Edison lamp is fifteen and a half candles, and certain professional gentleman have accorded ten seperate lamps per horse power, each of a power of twelve candles, or an average in in divided light of 120 candles per horse power. This is a serious error, on account of which the aforesaid professional gentlemen are entitled to our profoundest sympathies. If one of them were to tell a steamboater that it is as cheap to run a boat ten miles an hour as five he would be laughed at; but these great intellects experience no misgivings whatever in informing the public that it takes as little power to

overcome an electrical resistance of 150 ohms (as in Professor Edison's lamp) as it does to overcome a resistance of one or one-half or one-quarter ohm. What renders the voltaic arc lamp and generator of one electrician more powerful (and therefore cheaper, since the expenditure of steam power is the same in both cases) than the lamp and generator of another? It is the low resistance of his arc and generator. Why is a Maxim or a Hochhausen or a Siemens arc more powerful with the same expenditure of steam power than that of others? Because their arcs are, so to speak, "short and thick," of great quantity and low tension, while the failures are found in lamps of high resistance, and high tension is necessary to overcome high resistance. Electricity operates very peculiarly. If fifteen-sixteenths of a given current produces ten candle power the whole current (sixteen-sixteenths) produces more than twenty candles. To make an economical light, it is necessary, therefore, that the carbon shall be able to stand the final fraction of current. The first fractions produce but little light. To operate forty of the Edison lamps on the steamer Columbia required thirty horse power and the average light per lamp was less than six candles. Professor Edison proposes to use ground glass globes, because it is said that he has discovered that it is untrue that ground glass globes involve a loss of thirty per cent. in the light emitted. It is well known that ordinary clear glass globes occasion a loss of about twelve and a half per cent. It certainly will not be urged that a luminous point within a ground glass globe will yield as much light as in a clear crystal globe and as Professor Edison only claims fifteen and a half candles there can be no brilliant reason for reducing this light by obscuring it. The true reason is that the carbon horseshoe by its rapid disintegration so discolors a clear globe as to make such a globe objectionable. Hence, and very wisely, too, Professor Edison intends to use opalescent globes, preferably outside the clear globes, because outside opalescent globes especially do not discolor. But the loss in light is nevertheless very marked and very disadvantageous in point of economy.

Professor Edison places the cost of the plant for 800 of his lamps at that of an engine of 100 horse power and a dynamo machine absorbing that power. Owing to the high internal resistance of his lamps and the incapability of the horseshoe fibre to stand powerful currents Professor Edison has never been able to operate more than two of his lamps at twelve candle power each per horse power, and it is said that he cannot so operate them to-day and he is asserted to be unwilling to submit the same to a test before competent engineers. Professor Edison claims a life of six months' ordinary use for each of his lamps run at a power of fifteen and a half candles. This is so great an error in calculation that his present lamps, provided with enlarged carbons, will not run a week at that power, and his former lamps more than three hours without disruption of the fibre. The assertion that out of the profits derivable during the day from the supplying of electric power as against steam power, Professor Edison can afford to operate his electric light at night at a merely nominal price is so utterly absurd as to be unworthy of consideration; so also is the statement that as much electric power can be utilized out of 300 pounds of coal as steam power out of 700 pounds. That steam power from 300 pounds of coal can be made to operate an electric generator, which in turn shall operate an electric engine, each conversion of power being necessarily attended with loss, and that this electric power shall be as cheap as the direct steam power from two and one-third times that amount of coal, ought to be a proposition sufficiently striking to impress the mind of the most casual observer. On the contrary, the cost of electric power generated by steam engines and dynamo machines will be at least four times the cost of the original steam power. The statement made is far worse than that made a few years ago with respect to a Gramme electric machine, which was driven by a steam engine and the current from which was used to drive a second Gramme machine which was the counterpart of the first. It was said that seventy-five per cent. of the power of the steam engine was developed in the second dynamo machine, although (not to speak of the loss of power in the first conversion into electricity) the internal resistance of both machines was the same, and the current being necessarily divided equally between the two, the second machine, as it thus obtained only one-half of the current, could by no possibility have been able to convert into power, even if a perfect machine, more than fifty per cent. of the electricity generated in the first machine. The new Edison electric locomotive is said to go around extraordinary curves at the rate of forty miles per hour, and it is remarked that although the track is only about half a mile long this speed is almost instantly attained. This must be news to railroad men. There is no magnetic traction between the wheels and the rails, and yet, although the engine is very light, it is said to exert upon the rails a most extraordinary traction, enabling it to draw proportionately heavy loads up unusual grades. Perhaps this will be news to the coal carriers. I can imagine how anxious the Pennsylvania roads will be to try this new motor first where it will have the heaviest work to do—on freight trains. There are some other points of interest to elucidate, but as the world is likely to go round as usual for some time to come, it would appear to the casual observer that the foregoing ought to suffice for the time being.

All of which is respectfully submitted.

W. E. Swayer.

Complainant's Exhibit Crompton's Paper and Discussion. S. M. H., Ex'r.

[*Journal of the Royal United Service Institution, Vol. XXV., London, 1882.*]

WEDNESDAY, Jan. 26, 1881.

ON THE PROGRESS OF THE ELECTRIC LIGHT.

By R. E. CROMPTON, ESQ., Electric Engineer.

I think there is little doubt that the year 1880 will be looked back to as a year of great progress in the introduction of the electric light.

The commencement of the year was marked by the natural reaction in public feeling consequent on the disappointment which followed the collapse of certain famous promises with regard to lighting by electricity. People felt that little had been done towards solving the problem of the introduction of the new light into our streets and houses. A certain great name had been used as a lever by unscrupulous manipulators of the price of gas stock to unduly depreciate its value, and so produce a panic which had disastrous consequences to many holders. Part of the discredit which should have fallen solely on the ring of speculators who are responsible for the panic fell upon the electric light itself, and most unjustly so. This very materially retarded the progress and general introduction of the light. However, the possessors of good systems of electric lighting have lived down this feeling, and by perseverence in bringing forward and allowing thorough free trial of their systems they have, to a certain extent, re-established public confidence; indeed, we now see a second wave of interest has been excited, which I hope will gather greater volume until it culminates in the general adoption of the light.

There is a widespread desire at the present moment for more light; this is evident by the fact that even our

vestries have been driven to try the improved forms of gas burners which we now see at many principal crossings and street refuges.

This demand for more light, although it may be only a sentiment as regards our private requirements, comes to the front rank of necessities of modern scientific warfare. Darkness, that bugbear to the tactician, that friend to night surprises, secret expeditions, and the like, must no longer remain so. We must have darkness under control; in other words, having the means of readily and promptly lighting vast tracts of land or water to a brilliance only second to day by means of the electric light, we can have darkness at will.

Although every one has seen the electric light in lecture rooms, railroad way stations and streets, perhaps on account of the very various forms in which it has appeared and the mysterious way in which inventors have described new applications of it, seeming to go out of their way to impress on the public that they employ some new kind of electricity; no subject in which such very simple principles are involved has been so clouded over and little understood. I think it will aid your understanding of my description of the recent improvements in electric lighting if I divide the whole subject into two heads:

1. The means whereby we produce the required current of electricity.

2. The transforming of this current at any desired point into light.

Although Sir Humphrey Davy discovered the electric light eighty years ago, yet so long as the sole source of an electric current was a galvanic battery, expensive, fuming, uncertain and cumbrous, so long did the light remain a mere laboratory appliance. Faraday's discoveries in dynamic electricity gave a fresh impulse to the subject, but the great stride was made about ten years ago when a clever French workman, Gramme, combining in his dynamo-electric machine the self-exciting or reaction principle discovered by Wheatstone, Siemens or Varley (it matters not which), with his own annular armature, gave us for the first time a really cheap electric current; in truth, Gramme may be called the father of cheap electricity. The dynamo-electric machine consists always of the same series of parts, namely, a revolving spindle carrying coils of insulated wire so wound on to it that they can be moved at great speed through the lines of magnetic force of a powerful magnetic field. I call these machines self-exciting, because this very current that is generated in the revolving coils is used to excite the magnets themselves to give the required magnetic field. I have these coils, as wound in a Gramme machine, such as are working in this room to-night. You see they are wound in segmental-shaped sections on to a soft iron ring; all the ends of these sections are carried down to and connected with these copper segments, thus the whole of the coils form one continuous conductor, the wire of which is bared at the 60 points, where connection is made with the copper segments. If I cause this spindle with its coils, which is generally called the armature, to revolve between two magnetic poles, two currents flow into the two separate halves; thus, if I draw a line joining the poles, the currents which flow in the coils on one side of this line will be positive, and on the other side negative. It is most advantageous to collect these currents at a point midway between the poles, on each half circumference; we call this point that of highest potential, and the way we collect the currents is by allowing a metallic brush to rest on the copper segments above described at these points; as we collect positive electricity at one brush, and magnetic at the other, it is evident that if we connect the two by a wire, we shall get a continuous current flowing through it. In self-exciting machines, this wire before passing to the external circuit there to do useful work, makes many turns round the cores of the large magnets, and thus gives the powerful magnetic field.

These three elements, viz., 1st, revolving coils; 2d, collecting cylinders with brushes; 3d, wire from same exciting the field magnets are common to all dynamo-electric machines, the variations are chiefly in the

general arrangements and method of winding the coils. For instance in the Siemens machine, revolving coils, instead of being wound over and through an iron ring of considerable diameter as compared with its length, as in the Gramme above described, are wound over and across the ends of an iron cylinder of small diameter as compared with its length; the collecting cylinder, brushes, and exciting of magnets are the same as the Gramme.

The Bürgin machine, the armature of which I have here, combines features of Gramme and Siemens; instead of the coils being wound on to a single broad soft iron ring, this is divided into four narrower rings, or more properly, rectangles of soft iron wire. Each of these rectangles has a section of wire wound on to its flat side, leaving the corners of the rectangle bare; the object of this is to allow of greater magnetization of the soft iron; the collecting cylinder is similar to the other machines.

The Brush machine, which has lately been introduced into the English market, has a ring armature differing considerably from Gramme's, the ring is of cast iron, and has eight deep radial grooves in it; the wire forming the armature coils is wound into these grooves and fills them exactly flush with the surface of the iron; the collecting cylinder, also, is different to those above described; it is claimed for it that it is better suited for currents of extremely high tension and there is less chance of reversed polarity. It is so arranged that the current, instead of wholly passing around the electro-magnets on its way to the external circuit, is switched alternately through the magnets and through the external circuit. The large machines made on this principle give currents of six times the tension ordinarily given by the other machines. All the machines I have described give currents constant in direction, hence are called continuous current machines. I have not time here to describe machines giving currents alternate in direction; it is true that this is the oldest form of machine, and as such merits some consideration, but as this is not a history of the electric light, but a description of the latest machinery used for producing it, I have dwelt on those which are now most considerably used. I do not, for reasons hereafter to be mentioned, think alternating currents are suitable for your especial requirements—that is, the production of powerful lights having great fog-penetrating power; moreover, it is certain that alternating currents are dangerous to handle. All accidents to life or limb which have occurred with the electric light have been with alternating currents; of such was that on board the "Livadia," at Aston Park, Birmingham, and elsewhere: whereas, I am not aware of any accident having occurred with continued currents of moderate tension.

You now see how compact, simple and free from complications are the modern machines; there is only one moving part, the revolving spindle. We have to consider how best to work this. On board ship it has almost in all cases been worked direct by a high speed engine coupled to the spindle itself.

Brotherhood's engine, I am told, has been thus employed in nearly two thousand cases. Willans and Gynne's engines have also been used with success. The photographs on the table, which show you very neat arrangements by which one Brotherhood engine drives a pair of dynamo machines, and the whole will go into a space of 7'x2'x2', and thus occupy a very small corner of the engine room of an iron-clad; on land it is usual to drive these machines by belting; such is the case with the machines working to-night. A 10 h. p. engine, slightly modified from the agricultural portable engine, drives eight machines bolted down to a tumbril or carriage; the tumbril, with the machines on it, can be drawn on a good road by two horses, and can be coupled up to the engine, and all bolts put on in a few minutes.

Having shown you what ready and simple means we have at command for producing a powerful electrical current, we now must consider the best mode of turning this into light, and this brings me to the second part of my lecture. How does the electric current produce light?

Hitherto we have always produced light by raising bodies to intense heat, and so causing light radiance; at low temperature light radiance is small, at the higher temperature it is vastly increased. I need only remind you of the familiar illustrations of heated iron; at 1,000° F. it is red-hot, and the light radiance is trifling; at 2,000° it is white-hot, the light radiance is dazzling, it is increased fifty fold, although the heat is only double. Now, the electric light depends on no new gospel in this respect; by the aid of electricity we can raise bodies to extremely high temperatures, in fact, unapproachable by other means, and to cause them to afford an extreme light radiance. To obtain such temperatures we interpose bodies of high resistance in the path of the current. One fundamental law of electricity is that its currents develop heat in any bodies through which they pass, precisely in proportion to their resistance. It is not the place here to explain to you what is resistance; we do not know how electricity passes bodies, whether through or between their particles. At any rate, we do know that given two conductors of similar material, the conductor of the large cross-sections offers less resistance than one smaller, and conversely. The material also of the conductors is of the highest importance.

Taking two extreme cases, copper and silver are nearly equal to one another at one end of the scale, as offering least resistance. Carbon is at the other end of the scale, offering a resistance 150 times as great as either of the above; therefore, if you accept the fact that by interposing a high resistance you get a high temperature a slender rod of carbon appears as the most suitable material for us to use, and this virtually gives us the most simple form of electric lamp. I must here remark that I have inverted the usual order in which electric lamps are described. As arc regulating lamps were the first used, they are generally the first described, but as obtaining the electric light by means of the arc is decidedly not the simplest method, I propose taking the incandescent lamps first.

When we use a slender rod of carbon as a lamp by raising it to vivid incandescense by passing a current through it, we meet with a difficulty, the carbon burns away; it combines with the oxygen of the air to form carbonic acid. We must either exclude oxygen or provide means for replacing the carbon as it is consumed. The first method appears the simplest. In early days of the electric light, a great many efforts were made to enclose carbon in a glass globe, and obtain as perfect a vacuum as possible in the globe by means of an air pump. But the vacuum, if even at first tolerably perfect, never remained so for any time, and the carbon was slowly but surely destroyed. The next step was to remove the oxygen, but allow the nitrogen to remain; this, although it did away with some of the troubles due to leakage, still did not ensure long life to the carbon.

The nitrogen, although chemically inert, scoured away the plastic surface of the intensely heated carbon by the pelting action of the molecules. To ensure perfect durability, a perfect vacuum appears to be necessary, and this is, after all, what has been accomplished by our countryman, Mr. Swan, of Newcastle, in his beautiful little carbon filament lamp, which I now show to you. It is extremely simple, the carbonized thread is bent up into a double horseshoe, and connected to two fine platinum wires; the whole is enclosed in a little pear-shaped glass globe, from which the air is exhausted by a variety of the Sprengel pump, invented for this special purpose by Mr. Swan and Mr. Stearn of Birkenhead. The vacuum in these lamps is extremely perfect; you see what a pleasant soft steady light they give. I don't think any one could desire more in the way of a pleasant light for his house. As far as we know their durability is great; some of them have been in use for several months; at all events, I think you will admit that even if they only last a single month they will be a most perfect solution of the problem of lighting 'tween decks of ships, the cabins, and even have, I think, solved the knotty problem of safely lighting the magazine, for it is evident that by a second covering of strong glass they will be made absolutely safe, and I believe that even if fractured, the filament of carbon would immediately pass away like a breath before it could fall on and ignite any combustible.

The researches of Edison we have heard so much of were all in this direction; it is said that he has at last succeeded in producing a lamp somewhat similar to Swan's. Within the last few weeks another countryman of our own, Mr. Lane-Fox, has brought out a lamp very similar to Swan's, with, I believe, great success. I call all this class true incandescent lamps; there is no combustion: the whole of the light is afforded from the light radiance of the carbon heated to a high temperature by the passage of the current.

Another class, which I call the quasi-incandescent, do not protect the carbon from the action of the air: they provide a considerable length of extremely thin carbon rod, and pass the current through a quarter of an inch in length of one end of it, the light afforded by the incandescence of this piece is aided by that from its combustion, which thins down to the end, thereby increasing the resistance in, and consequently increasing the light. As the end wastes away the carbon rod is forced forward to crush it down, and this supplies new material for the action of the current. The Andre, the Regnier and Werdemann lamps are all varieties of this class, and have been fairly successful, but seem likely to be entirely superseded by the true incandescent class.

It is obvious that we can get a maximum resistance by making a break in the circuit, but such a resistance would be unmanageable with currents such as we use; we should get no current to pass; but if we pass the current through two thick carbon rods, the ends of which are first brought into contact and then slightly separated, the current does not cease to flow; we obtain a stream of fine particles of carbon across the gap; this is called the electric arc, and the intense resistance to the passage of a large current being concentrated on so small a spot, the temperature and consequent light radiance is from twelve to fifteen times that we can obtain from similar incandescence.

I will now put the current into a lamp, using the arc. You see what an enormous increase of light I obtain from the same electrical current as I am using with the Swan lamp. The intense whiteness of the light shows the enormous temperature which has been obtained at the surface of the upper carbon. You will wonder, then, why we do not always use the arc, so superior as it is in the amount of light and consequence economy of current. The reason is this: Once we make this break in the circuit to obtain the required resistance, that resistance no longer remains constant, but varies continuously, and through wide limits. We no longer use the same power of carbon, lasting for an indefinite time; on the contrary, the action of the current at the arc wastes away both carbons unequally, and in a variable manner. For your particular purpose you have not met with these difficulties to the same extent as we have in using the arc for commercial purposes. You use a hand-regulator, such as I have here. The carbons are carried in slides, and are moved toward each other by a sapper who works it, so that he, by careful watching, compensates these irregularities in the resistance, and so keeps the current pretty constant; but when we require the arc on a large scale, the lamps must be automatic, and we have to supply the place of the intelligent sapper by self-acting machinery. Some inventors, considering these difficulties too hard to face, met them in a half-hearted manner by altering the character of the dynamo machine; they went back to the use of the alternate current, and so were able to simplify the lamp down to what is called an electric candle, that is, they put two rods of carbon up side by side, and maintained them at a fixed distance apart by an insulating space filled with plaster of paris.

The arc, commenced at the top, is formed between two rods, the plaster being melted away by it as the carbons wear down. This is the famed Jablochkoff candle, which had wide application, but which has never been very successful in this country on account

of its want of economy and the very unsteady pink colored light given by the arc. Moreover, the alternating current, as I have before shown, is not suited to naval or military requirements, from its poor fog penetrating power and its being dangerous to handle.

Turning now to those who have faced the more difficult problem, we find that it consists of these main requirements. We have to provide by an arrangement for carrying a pair of carbons in such a manner that they can be approached towards each other, end to end, as those ends are wasted away. These ends must be touched together in the first instance, to allow the current to commence to pass, again touched together if at any time the light should be accidently extinguished; again they should be drawn further apart so as to lengthen the arc when the current is too strong and the converse when the current is weak.

All have approached this problem in the same way, in that they have obtained the controlling power over the movement of the carbons by the action of the current itself, exciting certain electro-magnets in the lamp, to work the proper mechanism.

Of five makes of lamps in very general use, viz., the Siemens, Brush, Brockie, Serrin and Crompton, the first three have a common feature in that they fix the lower carbon in a frame, the upper one descending towards it in a slide; Siemens retards its descent by cutting a rack on this slide, and gearing into a pendulum escapement, somewhat similar to that of a clock; an electro-magnet is so arranged that it lowers the slide gradually as the carbons are consumed, and when the magnet is at the end of its stroke it allows the escapement to come into action. If the carbons are approached too near, the strengthening of the current, thus caused, imparts a lifting action to the same magnet. In the Brush lamp, the retarding movement of the upper carbon slide is by means of a piston working in glycerine. In this lamp there is, also, an electric magnet which lifts, lowers, and locks the slide, so as to obtain the resistance approximately constant. In the Brockie lamp, no attention whatever is paid to the strength of the current, but at regular intervals of time, the upper carbon is dropped on the lower one and again raised at a fixed distance. This movement is worked by means of an electro-magnet, excited by a current separate from the lighting current, and having its own wire these regulating movements are, as it were, telegraphed to the lamp from the dynamo-machine, by means of a revolving contact-breaker worked at the machine, and making periodical breaks in the circuit of the separate wire.

In the Serrin and the Crompton lamps both carbons move; the lower one is fixed in a frame which can descend through a limited stroke so as to form the arc in the first instance, or if afterwards accidentally extinguished, the upper carbon descending only to supply the waste caused by the burning of the ends. In my own lamp I obtained a very great regularity in this movement, which we may call the feed-movement of the carbon; in all the other lamps the whole of the carbon and its rod has to be moved up or down whenever a feed-movement is requisite; in my lamp a very small part, only weighing a few grains, is to be moved by the slight weakening of the current, which we depend on to start this feed-movement. The delicacy of this movement is of the highest importance in obtaining a steady light from the arc. If the feed-movement occurs at long intervals of time, extreme unsteadiness and a flickering and ghastly coloured light follows; whereas if the movement is constant and regular, the arc is maintained of equal length, and if the carbons are of good quality the light will be steady and white. I now show you a Serrin lamp and one of my own. You will see how the irregularity in the feed-movement of the former affects the steadiness of the light; in the latter one, the movement you will see is almost continuous, and the arc remains practically of constant length.

Carbons also have been much improved of late; however good may be our lamps we cannot get a steady light unless the carbon be uniform throughout in hardness and resistance; the carbon must be very pure; any salts of sodium or calcium reduce the

resistance of the arc, and spoils the whiteness of the colour. The carbon used in the central lamp is very pure, and you see the light is perfectly white; this carbon in the third lamp in the stand gives a purple fringe to all shadows thrown by the light; the reason of this is, that impurities in it have decreased the resistance of the arc, consequently allowed it to become longer than it should be, a larger proportion of the light is given by the arc rays themselves than in the centre lamps, where the arc being extremely short, 90 per cent. of the light is given by the crater of the upper carbon.

This brings me to what I believe to be the true explanation of the superior fog-penetrating power of some electric lights over others. You will observe that the light of the electric arc comes from two sources: First, from the incandescent surfaces of the two carbons, that of the upper or positive one being cup or crater shaped, this crater affording 90 per cent. of the light, so long as the arc is short; to the first source must be added a little light from the glowing point of the lower carbon. The second source is from the arc rays proper; this light is not white but tends towards violet or purple; when the arc is long there is a greater preponderance of this colored light.

Now, I believe that the fog-penetrating power of an electric light is in proportion to the light which proceeds from the crater and from the point of the lower carbon. I believe the highly refrangible rays of the arc itself have little or no fog-penetrating power. In order to get craters of large size and intense temperature, we must use currents of low tension and great quality; high tension ones are comparatively useless. I have had considerable experience quite recently with electric lights during the continuance of heavy fogs at Glasgow, and my men have observed these facts, which I now lay before you.

I think that your present arrangement of using the electric light for discovering the approach of an enemy, say a torpedo launch, under cover of fog or smoke, is not a good one. You use the arc in a holophote placed down near the water line. Now, the holophote wastes a large proportion of the useful fog-penetrating crater radiance, and utilizes principally arc rays. I should prefer to mount a large arc light at a great height above the water, and set back the upper carbon, so as to direct the crater in the direction required to be observed, with little or no aid from reflectors. I think the light given by an 80 Weber current, properly regulated, would give command of a circle 200 yards diameter even in thick fog. I think, also, the look-out man ought to be placed considerably higher above the water-line than heretofore, although slightly below or to one side of the light itself, as it is evident that he should not look across or through the strongly illumined beam of fog.

I have now shown that we have at command a very complete and handy apparatus for producing the current, and using it either in the small units of light, as in the Swan lamps, or in the large arc lamps for lighting large spaces. I will not weary you with describing farther the great improvements that have been made in all the accessories which the continued use of the light have caused us to provide. Although the statistics of cost do not greatly concern naval and military requirements, yet you will no doubt be glad to hear that there has been a steady onward march in cheapening the light, and whereas a year ago, no one would contract to supply large arc lights, such as I have shown you this evening, for less than a shilling an hour—the same can now be supplied at eight pence.

In comparing the cost with gas, wherever we have had large spaces to light we have beaten gas many-fold, and even in small spaces, by using the Swan lights it appears that we have already halved the cost of gas.

At the Alexandria palace, electric lights costing four shillings an hour take the place of 2,500 gas jets costing two pounds an hour. At Mr. Swan's lecture, at Newcastle, he used 160 cubic feet of gas per hour to drive a gas engine, and so work a Gramme machine, lighting the lecture hall with thirty of his lamps, whereas 230 feet of gas per hour was used in the ordinary sun-

burner to give a very inferior degree of illumination; these figures speak for themselves. I could quote you many other cases, some showing greater and some less comparative economy; but it is evident that if the electric light were now produced on the same scale and with the same vast appliances as are used for producing gas, we should have a still larger margin of economy.

I will conclude my lecture with an imaginary scene of disembarkation of a large army carried on at night. It may be often necessary, on account of a dangerous coast of signs of approaching bad weather, that this operation should be carried on with the utmost speed by night as by day. All the apparatus for producing the current would be retained on board the steamships; the conducting cables need only be passed on shore. Tripod stands to carry the lamps would be placed at convenient intervals along the beach. The whole arrangement for lighting a mile of foreshore could be got into position and the lights shown with less than an hour's work by squads of men properly trained in the use of the apparatus. The most difficult operations, such as landing guns and horses, will be as easily carried on by night as by day. If extreme celerity were needful, it is not absolutely necessary to land the lights; the lanterns may be hung in such urgent cases from spars rigged out on the steam tenders or launches, the dynamo machines being worked, as before, on board the large ships.

A distance between these, *i. e.*, between the machines and the lights, may be as great as a mile without causing a cable to be unnecessarily heavy. I have not dwelt on the advantages which the light gives for the night signaling, as they are sufficiently obvious; but this brings me to the third part of my lecture, which, although on a subject connected with electricity is connected but remotely with electric light, namely, the photophone of Professor Graham Bell.

Four years ago Professor Graham Bell's researches culminated in the telephone—the sending of articulate speech by means of electricity. Since then, another series of brilliant experiments have had for their result an invention of perhaps equal importance—the photophones sending sound or even articulate speech by means of a beam of light.

Graham Bell has been for years experimenting with silenium, that curious substance which has the property of varying its electrical resistance according to the intensity of a beam of light falling on its surface. At an early period it had occurred to Bell to utilize this property in signaling or recording the changes of the intensity of a beam of light even to distant stations; but he was baffled in carrying this out by the very irregular and almost unmanageable resistance of silenium in its simple state.

Bell, with whom throughout these experiments has been associated with Mr. Sumner Tainter, then made an elaborate series of trials of various compound arrangements of silenium with other and better conducting substances. Their wish was to prepare what they termed a silenium cell, which would have a resistance far lower than simple silenium and yet retain all its sensitiveness to the action of the light. Almost at the same time Professor Adams, Willoughby Smith, Werner Siemens, Lord Rosse, Draper, Sale and others were carrying out independent investigations of the properties of silenium. Werner Siemens produced a cell which was tolerably satisfactory, but Bell and Tainter found that by using discs alternating of mica and brass, the mica being slightly smaller than the brass, and the minute grooves formed on the built up cylinder being filled with silenium, they had produced a cell the resistance of which varied from 300 ohms in the dark to 150 ohms in the light. At a somewhat earlier stage, Bell had proposed to use a telephone as a delicate test of the minute changes of current which it is necessary to take note of when investigating the changes in the resistance of silenium under the action of light, and in May, 1878, at a lecture at the Royal Institution in Albemarle street he announced his belief that it would be possible, by means of a telephone to hear a beam of light fall on a silenium cell, and thus bring acoustics to the aid of optics. From this point, the progress was rapid. A few days afterwards Willoughby Smith announced that the prophecy was fulfilled: he had heard a beam of light on a bar of silenium by means of a telephone in circuit with it.

The next step was to devise an arrangement by which a beam of light could be thrown into rapid and rhythmical vibration and so produce a musical tone. This Graham Bell and Tainter accomplished by a rapidly revolving shutter, which alternately covered and uncovered a slit through which a beam of light passed, thus interrupting the beam at regular intervals of time. When a beam of sunlight thus interrupted was allowed to fall on a silenium cell, a loud musical tone was heard from a telephone in circuit with it, and thus the musical photophone became an accomplished fact. Hence, to cause the beam of light to vibrate in unison with the humane voice was a trifling step. An elastic mirror was provided, made of either mica or very thin or microscopic glass, silvered on the one face, to reflect the beam of light, and so placed that the voice could be directed against the back face. When spoken to, this mirror vibrates in exact unison with the voice, and the beam of light reflected from its front face also vibrates. By means, then, of this combination—first, the sunlight collected by a lens and thrown on the face of the vibrating mirror; second, after being reflected, the rays being rendered parallel by the lens, and thrown to a distant station; third, there to be condensed by a parabolic mirror on to the surface of the sensitive silenium cell; fourth, the ear applied to a telephone in circuit with the cell—the articulate speaking photophone also was accomplished.

Bell and Sumner Tainter conversed across a distance of 240 yards at Washington, the sole medium of communication being the vibrating beam of light. In Graham Bell's words, "On putting my ear to the telephone I heard distinctly from the illuminated receiver, Mr. Bell, if you hear what I say, come to the window and wave your hat."

I have thus given you very briefly the history of this wonderful discovery. It is impossible without diagrams, and without putting the apparatus before you, to make this very interesting, but at the same time somewhat complicated, matter, clear to a large audience.

The photophone in its present stage is a subject rather for the laboratory than the lecture room. I must thank you for the kind attention that you have paid to my lecture. I had intended to illustrate it much more completely by experiments and apparatus than I have done. In that part of it, as a manufacturer and engineer, I should have felt more at home that in the more descriptive portion of my lecture.

The very extraordinary stoppage of traffic caused by the snow storm, has, in spite of the postponement of my lecture, prevented a great part of my apparatus reaching me in time, this I beg you will excuse.

Captain Curtis, R. M: With reference to the position of the look-out man, I think instead of putting him at the mast head, he would see much better slung over the ship's side, having the water's edge so as to give him a view nearly on a level with the horizon (commonly called sky line). I think he should be under instead of above the light.

Mr. Liggins: I should like to make one suggestion; great complaint has been generally expressed, particularly by ladies, about the whiteness of the electric light and the deathlike tint it sheds on faces; is there any practical objection why that whiteness should not be modified by slightly tinting the glass shade? The light would be far more useful and would be better approved of if it was of a more agreeable color, for instance, either a slight pink or a slight yellow tint.

Mr. Spottiswoode, President, R. S: I very gladly respond to the call of the Chairman, although the lecturer has, on this occasion, left me very little to add. He has described in a very distinct manner, the progress and present position of the electric light, which certainly seems to have now arrived at a sufficient degree of efficiency to become practically useful. The lecturer has also described the various machines already in use for the protection of the light; and it is quite clear

that although they differ in essential details of construction and even also in efficiency, yet they are all sufficiently good for practical purposes. With regard to the more general adoption of the light, the great difficulty, as the lecturer has pointed out lies in the lamp or burner. During the past year the whole subject has been differentiated in a manner not hitherto attempted, nor indeed required. Different kinds of lamps have been devised for different purposes; and it is through such differentiation that we may hope to see the light more generally used than it is at present. One class of light is wanted for large open air spaces; another, for large or enclosed spaces, such as railway stations and public halls; a third kind for factories; and lastly, another kind for domestic purposes. For the first purpose, undoubtedly large centres of light are the great desideratum. In several of the thoroughfares of London, lights have been erected which have undoubtedly added very much to the illumination of our streets, though it may still be a question whether that is the form of electric light for the town illumination of the future. In some places, particularly the docks, Dr. Siemens has erected lights on a large scale and at much greater elevation; by their means he has effected a complete illumination of the area required. Not only have the spaces outside of the several workshops been illuminated, but even the interior of such of the workshops as have partially glass roofs received illumination after the fashion of day light. It remains, however, to move still further in this direction, and I sincerely hope that before very long experiments on a still larger scale, with more powerful lights at a much greater elevation, will be tried. By this means it is hoped to obtain a greater abundance of diffused light by reflection from buildings and other solid objects, by the scattering of rays of light from the small particles floating in the air; and to imitate much more closly than has yet been done, the action of the sun or day light. For the illumination of workshops and houses, the all-important feature is steadiness, and everything that can be done in this direction is of paramount importance. I understand from Mr. Douglass of the Trinity House, who has perhaps had the largest experience in observing the electric light, that it is not so much the intensity that injures the eye, as the irregularity or flickering of the illumination; a consideration which gives the highest value to the quality of steadiness. In the case of a factory, of course we do not want one great light, but a variety of lights of more moderate extent, so as to illuminate the different portions. For this purpose, Mr. Crompton has, I think, succeeded beyond any others. As regards domestic purposes, we have here the very beautiful invention of Mr. Swan; he certainly is the first in the field so far as this current is concerned. With these lights it will be worth while to sacrifice a considerable amount of illumination in order to get a light of this degree of moderation and steadiness for the interior of our buildings. There are, I believe, one or two other inventions for the same purpose already advanced; and I hope, without disparagement to Mr. Swan's light, that we may see others come forward with other solutions of the problem of domestic lighting. I heartily wish to join my thanks with those of the audience to Mr. Crompton for his interesting lecture.

Mr. St. George Lane Fox: I believe that Mr. Edison, who, of course, is referred to in the beginning of the lecture, though he is an American, has really done a very great deal for this subject. He began a work, it is true, perhaps, rather got up, as it were, by speculators and gas people, but I think great credit is due to him for having stated from the very first that it was possible to introduce a system of electric light that could be so distributed and divided as to be available for household purposes. I think Mr. Edison was the first, and not Mr. Swan, to produce a practically useful lamp on the incandescent principle with a filament of carbon in a vacuum. Mr. Edison's researches too, in respect to the presence of occluded gases in metals and other substances, are exceedingly interesting and very sound and scientific in the manner he has carried them out. I think he has rendered very great service not only to the future of electric lighting,

but also to science by his investigations, and for this proper credit should be given him, more especially as in the future he will be able to show, and I have no doubt, will show, that he was the first to succeed, and I think it as well to recognize it at once. I say this entirely disinterestedly, because it is very much to my disadvantage that Mr. Edison should be first, as I have also claims in this direction. There is another point to which I may call attention, and that has reference to the reason why more light is produced in the arc light for a given amount of power than it is in the small incandescent lamp. It was not, I think, quite right to say that this is due to the greater resistance in the arc light. The arc light has a resistance, probably one hundred times less than one of those small incandescent lights that you see above you. I fancy their resistance is about 100 ohms, whereas the resistance of the arc light is not more than one, or it may be, perhaps, two or three. The fact is, you cannot get an arc light with a very high electrical resistance. The real reason for this difference, there can be no doubt is, that a greater amount of energy is expended in a smaller space in the case of the arc light than of the incandescent light. In the arc, you have an immense concentration of force in a small space; the result is that the luminous radiance is far greater in proportion to the amount of energy expended. Again, I cannot agree with Mr. Crompton in saying that the arc light is very much cheaper than the incandescent light. The incandescent lights, as you see, have a very great advantage over the arc light, and I think they will ultimately have the advantage of economy. It is altogether another question to estimate the economy in point of horse-power required, or in point of the amount of money which one would have to pay for a given quantity of light. It is true that in an arc light the amount of energy required to produce a given amount of light is very small in proportion to that required for the incandescent light, but an arc light always requires a considerable amount of attention; and there can be only a few produced from one generating machine, therefore we want an increased expense in plant, besides a great expense is incurred in the carbons themselves. It is a fact that energy can be produced by the combustion of 1½ lbs. of coal per horse-power, per hour, that is a very good result which is now practically obtained, for there is a firm in Greenock, prepared to supply engines with that guaranteed consumption. The cost of 1½ lbs. of anthracite coal, the best coal for this purpose, is only $\frac{1}{10}$th of a penny, and, I think, on a very large scale other expenses would be found comparatively insignificant as compared with the expense of gas works. Fuel employed in producing the power would be the chief cost for these small lights. Such lamps as those will probably be produced before long at a cost of one shilling each; there is hardly any expense of material in them, and they take less than an hour to make. I might add that the energy required to produce one of these lights is very much less than the amount of energy required to produce that powerful arc light. I believe that the proportion of energy is as twelve to one; that, in fact, a good powerful electric arc will give twelve times as much light as the incandescent light for the same expenditure of energy. You can raise these filaments to a higher temperature, but it is not safe to do so, because the carbons will not endure it long, but for all practical purposes, if the temperature is kept down the lamp is indestructible.

Captain Long, R. N.: I should like to ask if Mr. Crompton would supplement the information which he has already so kindly given us about fog, by some statement as to the distance at which he found at Glasgow he could see an object with tolerable distinctness from the lamps, and also whether it could be argued from the illumination of a place in a given fog in a given weak light, what would be the illumination of a place in the same fog at a greater distance by a light of much greater power.

Mr. Crompton: With regard to the question as to the look-out men being placed above or below the light, that is a point on which I will bow to the judgment of

those who have been on the look-out themselves. But I have been in a very elevated position, looking after an electric light on a mast 80 or 90 feet high, and I certainly could distinguish objects best when I was high up. I could distinguish them by foreshortening them when I got off the ground glare. I do not know that the case is identically the same on the water as on land, but I am under the impression that one of the great causes why it is so difficult at present to see a torpedo-boat approaching when the look-out man is placed low, is that mentioned by Capt. Curtis, when he said he wished to get his eye as near the horizon as possible. That is, of course, all right when you want to see one object relieved against the light behind; but, I conceive, if you want to clearly distinguish what an object is, the higher you get and the more foreshortened the sight you can get of the object, the easier you are able to distinguish the nature of it, whether a friend or an enemy, a torpedo-boat or a harmless craft.[1]

Next, as regards the whiteness of the light. It is not fair to blame the light for being white. I do not think ladies would long object to the light if it were white. It is when it gets beyond white, blue and purple, then it is so objectionable. The light is never absolutely white; it is always on the yellow side, and so long as it remains on the yellow side it is all right. Yellow is a becoming color to our complexions; the most unbecoming color you can use is pink. I have tried putting pink shades on the light, and it makes everybody look yellow, whereas if you put yellow shades to the light, it makes everybody look pink. I have yellow glass here.

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[1]This question of the most favorable position to place the look-out men to distinguish objects in thick weather by aid of the electric or other artificial light, is a very interesting one, and deserves more space than can be here given for its answer. As far as my experience guides me, the position of the man may be varied through considerable limits, according to the density of the fog itself, the great point being that he should be able to look at the object to be observed from a point well outside the bright beam of light, in all cases retaining his advantages of foreshortening the object as much as possible.

It stops a great deal of the light, but it prevents the light hurting your eyes. Of course the objection to its use is that a large proportion of light is wasted. First, I should say with regard to Mr. Spottiswoode's remarks, that he has really hit the pith of the matter when he says, that if we want a light with great economy we must use large lights—hang up young suns; we must hang up something that will supply the place of the sun, and Siemens certainly has done that to a great extent at the Albert Docks. But the suns to be useful must be suns with this large crater that I spoke of; and in order to get the full advantage of the crater you must have your light at great elevation. It is no use hanging up small lights at a great height; you want lights with a current of low tension but enormous quantity, and then you get those suns which have a high fog penetrative power. In reply to Mr. Fox's remarks about Mr. Edison I may say that he misunderstood me if he thought I cast any slur upon Mr. Edison as an inventor; I did not. What I blame Mr. Edison for was allowing his name to be used as a lever.

THE CHAIRMAN: Allow me to say that in this theatre we always endeavor to avoid, if possible, anything that looks like a question as to priority of invention. There is the great difficulty in deciding the question, and I therefore wish to caution you against a rock which is sometimes ahead in these matters.

MR. CROMPTON: Of course the fact that Mr. Edison has been always put forward as the leader in electric light invention has, to use an American expression, "rose" people a great deal in England; but I will not say anything further about Mr. Edison. With regard to the comparative resistance of the carbons in the incandescent system and in the arc system I think I am really at one with Mr. Fox. There is no doubt that the resistance of the arc must be much higher at any certain point, otherwise you could not get the higher temperature; but it is an extremely difficult matter to describe and put into language which fully makes this

point clear, and I am afraid my language is at fault in this case*.

The resistance of that large light was, as he said, about 1 ohm, and the resistance of each of these incandescent lamps is, we will say, about 150 ohms. But, I repeat, how is it we get that temperature if we have not an enormous resistance? And I think that over every portion of the crater of that arc there is enormous resistance at each point. I quite agree with Mr. Fox, that the great improvement which has taken place during the year has been the introduction of this incandescent light. Of course I, who have been using to a great extent the electric arc, like every shoemaker who sticks to his last and swears by it, still consider the electric arc is very good in its place, but I admit, as freely as any one does, that those gentlemen who have brought forward the beautiful incandescent light are the greatest inventors of the year. With regard to the question about the area that can be lighted, when the weather is foggy or there is smoke hanging about, that is entirely a question of degree. I have a light giving a crater one-quarter of an inch in diameter with a 30-Weber current, raised 90 feet from the ground, in a goods yard at Glasgow, and on clear evenings you can read the labels on the goods wagons about 220 yards away from the light. On the foggiest evenings we have in Glasgow, you can only read those same labels about 40 yards away from the light. But I am perfectly sure if, instead of using a 30-Weber current, I had a 80-Weber current, as they have in use at Chatham and in the navy, I should have been able in a fog of the same thickness, to have read the labels at a distance of 200

* Probably the resistance of the electric arc is determined by the cross-section, if I may use such a term, of the stream of particles of carbon which are passing across it. If these could be condensed into a solid wire connecting the electrodes, this would be exceedingly fine, and its proportionate resistance to the passage of the large current used with the arc would be just so much greater than the resistance of the filaments of carbons in Swan's lamps to the passage of their currents, as is the temperature of the former greater than that of the latter; possibly the difference is as great as 12 to 1.

yards. At all events it is a purely comparative question; there may be fogs so thick that you cannot see anything; but in the ordinary fog, I am certain that the large light would have enabled us to read at that distance. Fog, although it stops the light in one sense, is rather a help to the light in another, for it distributes it, and, as Mr. Spottiswoode has explained to you, the particles of fog reflect the light in various directions; they break it up, and the fog and steam in a large railway station, when the lights are hung high up, have by no means an unpleasant effect. We have a very nicely diffused light, and if the lights are tolerably powerful there is not much loss. I might have referred to the occluded gases, with regard to which it is said Mr. Edison has rendered such yeoman service. I can only say I brought forward Mr. Edison's name as having made trustworthy researches on occluded gases at a meeting of the Mechanical Engineers at Barrow-in-Furness, and my remarks were received with considerable derision, as his researches were not considered to have scientific value of that kind.

The Chairman: I am sure that you will all agree with me that the most cordial thanks we can give are due to Mr. Crompton for his excellent lecture. The number of instruments he has brought forward show the trouble he must have taken to bring before us this most interesting subject. It is one of the subjects of the day and it is evidently making great progress. On the Thames, the new Albert Dock is lighted by electric light, and as far as I know the only difficulty has been so to screen the lights from the river itself, that while lighting the docks it should not dazzle the people who navigate the river. That has been accomplished, and I do trust the electric light may make further progress. With regard to the few words our zealous Secretary was good enough to ask Mr. Crompton to give us with regard to the photophone, I trust that in another year we may have a full lecture upon that most interesting and remarkable instrument. I will now, in the name of the meeting, thank our lecturer for his very interesting lecture.

Complainants' Exhibit
"Extract from Sawyer's Book on
Electric Lighting" Jany 22. 1890
D.M.H. Ex'r

CHAPTER IV.

INCANDESCENT LAMPS.

PRODUCING light by heating a poor conductor of electricity to incandescence is a favorite conception of experimentalists, and numerous attempts have been made toward its practical realization. In nearly every instance these attempts have resulted in failure, not so much because of any inherent defect of principle as because of imperfections in the details of construction and operation.

Lighting by incandescence involves a principle as simple as lighting by the voltaic arc. The conductor rendered luminous is of poor conductivity, or, in other terms, of high resistance. The resistance of the wires connecting it with the generator of electricity may be disregarded. Therefore the current generated is divided between the generator and the poor conductor exactly in proportion to their respective resistances; and as the latter is contained in small compass, the current is concentrated at a small point and there produces calorific effects sufficient to yield light.

When a body is at the temperature of 1,000° C. we have the heat-rays:

At 1,200° we have the orange rays.
" 1,300° " " " yellow rays.
" 1,500° " " " blue rays.
" 1,700° " " " indigo rays.
" 2,000° " " " violet rays.

Above 2,000° C. we have all the rays of the sun. In incandescent carbon lighting the conductor is raised to a temperature much in excess of 2,000°.

Many conductors may be employed in the production of light by incandescence; and it is a curious fact that experimentalists have almost invariably followed a beaten course, passing from one metal to another: from platinum to iridium and iridio-platinum; from the metals to carbon-coated and intermixed asbestos and other refractory materials; and finally to carbon alone. As carbon, pure and simple, has been clearly determined to be the only suitable substance, we shall leave out of consideration all other conductors of electricity.

There are two types of incandescent lamps in use, those which burn in the air and those in which the luminous conductor is enclosed in a globe exhausted of air or containing an atmosphere of nitrogen or other gas for which carbon at high temperatures has no chemical affinity. The open-air lamp is subject to so many objections that it is doubtful whether it will ever be successfully employed; but the efforts of Renier and Werdermann have done much towards reducing it to practical form. The Renier lamp (Fig. 34) consists of a long pencil of carbon continuously fed between an elastic contact to a bearing upon a carbon roller at a point between the vertical and the horizontal. The upper or elastic contact compresses the pencil laterally, and one terminal of the conducting wire is connected with this contact. The other terminal is connected with the carbon roller. The pencil, being consumed at the lower extremity more rapidly than at any other place, diminishes in length, and this diminution is compensated by the continuous downward feeding of the pencil. Rotation of the carbon roller to carry away dead fragments of carbon is obtained from the tangential component of the pressure of the pencil on the periphery of the roller.

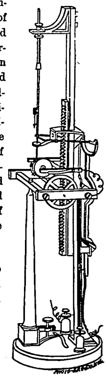

Fig. 34. Renier's Lamp.

The Werdermann lamp (Fig. 35) is the reverse of the Renier lamp in construction and operation. In this lamp the carbon pencil is fed upward, through an elastic contact, by means of a weight or spring, against a solid stationary block of carbon.

Both the Renier and the Werdermann lamps, under proper conditions, should yield a higher percentage of light per horse-power than lamps in which the carbon is protected from oxygen; but in both these lamps the constant renewal of the carbon pencil and points of contact necessary are objections to be surmounted.

The earliest attempt to isolate an incandescent carbon conductor from oxygen appears to have been made by

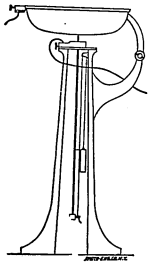

Fig. 35. The Werdermann Lamp.

Starr in the year 1845;* and it is a matter of some surprise that this patient investigator, whose conception included the entire range of divisibility of the light, should have stopped but little short of realizing a practicable system of lighting. The Starr-King burner (Fig.

* Starr-King; English patent No. 10,919, 1845.

36) consists of a conducting wire, D, sealed in the glass of a Toricellian vacuum-tube, and connecting with a carbon rod, A, whose lower extremity is in contact with a second conductor resting in the quicksilver. The bar B, of porcelain, serves as a support for the apparatus. For several reasons this lamp could not have been a successful one, as will be made clear in another chapter.*

In 1873, nearly thirty years later, came the invention of Lodyguine,† a Russian physicist, who was awarded, during the subsequent year, the great prize of the St. Petersburg Academy of Sciences. The Lodyguine burner consisted of a single rod of carbon diminishing in section at the incandescent part; and two or more of these rods were placed in a globe provided with an exterior rheotome, in order that the current might be

* The Starr-King system of lighting included a generator of electricity some of the devices of which are variously used at the present day. The following summary of the leading points of Starr's English patent, taken out by King in 1846 (No. 11,188), and entitled "Improvements in the Production of Magneto-Electricity," is of interest:

1. The principle of the machine consists in revolving between the poles of permanent magnets, arranged radially, a disk having near its edge bobbins with their axes parallel to the axis of rotation.

2. Winds around the iron cores a continuous flat strip of copper, inserting cotton between each layer to insulate.

3. Collects the current from the separate bobbins with separate springs, to allow of subdivision, if necessary.

4. To prevent neutralizing currents being induced in the brass or other metallic plate which forms the wheel carrying the armatures, a saw-cut is made from the edge to the hole in which the armature is inserted.

5. Attaches a soft-iron bar to the inducing magnets, so that they may each act a second time on any armature during each revolution.

† Meanwhile both Shepard in 1850, English patent No. 13,802, and Roberts in 1852, English patent No. 14,198, invented and experimented with incandescent carbon lamps.

passed through a fresh carbon when one should have been destroyed. Unaccountably, Lodyguine has been severely criticised by many writers, who have pronounced his apparatus the least practical and the least

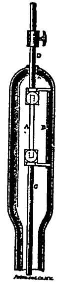

Fig. 36. The Starr-King Burner, 1845.

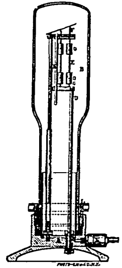

Fig. 37. The Konn Lamp.

studied of all; whereas it was the most practical and the most studied of all that had preceded it, for Lodyguine recognized the value of a perfect connection with the incandescent portion, such as results from enlargement of the carbon at the points of contact with the conductors leading to it, and he provided for the inevitable destruction of the rod by arranging another to take its place.

After Lodyguine came Konn and Kosloff, whose inventions do not differ essentially, although the Konn lamp of 1875 (Fig. 37) was perhaps the more practicable. This lamp consists of a base, A, in copper, on which are fixed two terminals to which the conductors are fastened; two bars, C D, in copper; and a small valve, K, opening only from within outwards. A globe, B, expanded at its upper part, is clamped to the base by means of a collar, L, pressing on soft rubber washers. One of the vertical rods, D, is insulated from the base and communicates with a terminal, also insulated. The other rod, C, is constructed in two parts: (1) of a tube fixed directly upon the base and in electrical connection therewith; and (2) of a copper rod split for a part of its length, whereby is obtained sufficient elasticity to permit the rod to slide freely and yet be held in place in the tube. Carbon pencils, E, are placed between two small plates which crown the rods. Each pencil is introduced into two small blocks, O, also of carbon, which receive the copper rods F G at their extremities. The rods G are equal in length, and the rods F are of unequal length. A hammer, I, is hinged on the bar C, and makes connection only with a single pencil of carbon at once.

When the lamp is placed in circuit, a pencil of carbon, E, is traversed by the current; and when this pencil is consumed and drops out of place, the hammer, I, makes connection with another pencil; when all the carbons have been consumed the hammer rests upon the copper rod H, and the circuit is not interrupted. According to M. Fontaine, the maximum light obtainable from a Konn burner is equal to about 175 candles. The

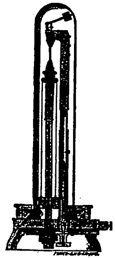

Fig. 38. The Bouliguine Lamp.

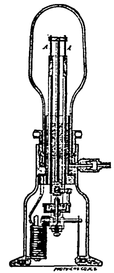

Fig. 39. Fontaine's Lamp.

carbon is protected by partially exhausting the air and depending upon the carbon monoxide, subsequently formed, to preserve it from further change—an error in calculation which it is difficult to understand, and the fallacy of which is proved by the results. The average duration of the first pencil is about twenty minutes.

The succeeding pencils have each an average life of two hours.

Next in practical order comes the Bouliguine lamp (Fig. 38), in which a long pencil of carbon is fed upwards, as in the Werdermann lamp, through an elastic contact, in this case controlled electro-magnetically. The sealing

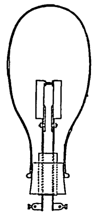

Fig. 40. Farmer's Lamp, 1879.

of the globe is effected, as in the Konn lamp, by the lateral pressure of soft rubber washers.*

The last of these old lamps of which there is record is the invention of M. Fontaine (Fig. 39), in which the carbon pencils, A A, are held in rigid contacts. No

* Carbon-holders, made in the form of long tubes and filled with long carbons, were first employed by Staite (English patent No. 12,212 of 1848), who, with his associate, Edwards, was much in advance of the day in which he worked.

allowance is made for expansion or contraction of the conductors. In this lamp, as in Lodyguine's, a fresh pencil is brought into circuit by an exterior rheotome when one has been consumed.

Among all these lamps that of Konn maintains its supremacy; and it must be confessed that, considering the time and means devoted to the solution of this problem in European countries, the product is insignificant.

The lamp illustrated in Fig. 40, which was patented by Farmer, March 25, 1879, has not progressed beyond the stage of laboratory experiment. It is perhaps less practical than the lamps of Konn and others, in these respects: that the incandescent rod or pencil is held between large blocks of carbon in such a manner as to greatly obscure the light; and that the sealing is effected by means of a rubber stopper through which pass the conducting supports, which, being good conductors of heat, must inevitably cause the lamp to unseal.

CHAPTER V.

CARBONS FOR INCANDESCENT LIGHTING.

BEFORE entering upon a further survey of the field of incandescent lighting, it is well that we should pause to consider the primal element of all incandescent lamps—the luminous carbon conductor. Its requirements are simply expressed. In cross-section it must be uniform and in homogeneity perfect. The denser and harder the carbon the more lasting it proves to be; and density, hardness, and homogeneity in the carbon are therefore the elements, or a part of them, of success. Before the time of Foucault, who substituted gas-retort carbon for wood charcoal, the voltaic arc was little more than a laboratory toy; and thus with incandescent lighting, so long as the luminous conductor is confined to the product of the gas-retort its uses must be confined to the laboratory.

One of the earliest methods of preparing artificial carbons, and that in most general use at the present day, consists in reducing coke to a fine powder and thoroughly incorporating it with molasses or other glutinous hydrocarbon substance. The resultant mixture is pressed into moulds and baked, and afterwards placed in a concentrated solution of the same hydrocarbon, and, when thoroughly saturated, again baked; and so on until it acquires the requisite solidity and smoothness. Such carbons are imperfect, since they contain many impurities.

By the Jacquelin process carbon is produced which, in purity, density, hardness, and homogeneity, is all that could be desired. M. Jacquelin, with pure hydrocarbons, closely imitates the processes of the gas-retort, decomposition of the compound gases being accomplished in a highly-heated porcelain tube, upon the interior surface of which the carbon is deposited. The objection to this process consists in the difficulty of reducing the mass thus formed to the shape of rods or pencils, as the carbon obtained is so hard that it can be cut only with the greatest difficulty.*

The best artificial carbons for incandescent lighting that we have obtained are made by the Carré process, and supplied by M. Brèguét in mechanically perfect round pencils of from eight to twenty inches in length, and almost any desired diameter in millimetres; but in these carbons there is room for extensive improvement which, no doubt, M. Carré will turn to advantage. According to Fontaine, the process of manufacture is as follows: A composition, consisting of very finely powdered coke, calcined lamp-black, and a syrup formed of twelve parts of gum and thirty of cane-sugar, is thoroughly ground and intermixed, and sufficient water is added to give the required consistency. Thus prepared

* Within a few days we have experimented with a smooth disk of celluloid, revolving at a high rate of speed, and we find that by means of it the hardest retort-carbon is as easily and smoothly cut as so much hard rubber. This would seem to promise a similar result with Jacquelin carbons.

the paste is compressed and passed through a die-plate, whereby the pencil is formed. Subsequently the pencil is subjected to a high temperature in a crucible, and by various operations and repetitions of the heating the requisite density and hardness are obtained. The arrangement of the pencil for baking, after forming, while yet in a pliable condition and without permitting it to twist or bend, is one not fully understood; and all attempts in this country towards duplicating the manufacture have signally failed. Pencils of one thirty-second of an inch in diameter and nine inches in length, made expressly for us, are as absolutely straight and regular as a wire under tension.

The drawn or moulded pencils are primarily placed in a horizontal position on a bed of coke-dust in crucibles, each layer being separated from its neighbor by an intervening sheet of paper. Secondly, a layer of coke-dust is spread over the carbons; and, lastly, the whole is covered by silicious sand. Having been kept at a cherry-red heat for four or five hours, the carbons are removed to a vessel of boiling-hot, concentrated caramel or sugar-cane, and there left for two or three hours, the syrup being alternately cooled and heated several times, in order that it may completely permeate the pores of the carbons. Subsequently the syrup is drawn off, and any sugar adhering to the surface of the carbons is removed by immersion in boiling water. Finally, after drying in an oven, whose temperature attains to 80° C. only in the course of twelve to fifteen hours, the baking operation is repeated. Upon the number of repetitions of this process, to a certain extent, depends the value of the carbons, which, specially manufactured, are marvels of purity, tenacity, density, and homogeneity.*

* The following synopsis of old English patents relating to electric-light carbons, taken from Col. Bolton's report, will doubtless prove of interest:

1846. GREENER AND STAITE, 11,076. "Certain Improvements in Ignition and Illumination."

Uses lamp-black, charcoal, or coke, already purified from sulphur and metallic mixtures by the application of electricity in accordance with the process patented by Jabez Church in 1845; digests in nitro muriatic acid; washes several times in water or in some weak alkaline solution, or carburetted alkaline solution, finally with distilled water; then dries and presses with hydraulic screw, or fly-press, into cylinders, and when necessary exposes to intense heat in a furnace for twenty-four hours.

1846. STAITE, 11,449. Takes equal quantities of coal of a medium quality (neither too rich nor too poor) and of that purified description of coke known as "Church's Patent Coke"; powders and compresses in close sheet-iron moulds until solid, then plunges into concentrated solution of sugar, and when sufficiently dry subjects it for several hours in a close vessel containing charcoal at an intense white heat.

1847. STAITE, 11,783. In addition to pressing, also heat, and when hot plunge into sugar melted by heat without the aid of any liquid. Then cool and place in a closed vessel containing pieces of charcoal heated to a white heat, and keep there for many hours, or even two or three days; or the whole mass may be a second time immersed in melted sugar and the process repeated.

He says, also, that electrodes made of gas-retort carbon frequently contain iron, which makes them split and not give out so much light. They may be much improved by heating to a white heat in a closed vessel for some days.

1848. STAITE, 12,212. Prefers to use, 1st, plumbago powder having iron, etc., extracted by washing and warming in acids; 2d, lamp-black; 3d, charcoal powder; 4th, powder of carbonaceous concrete which is deposited in gas-retorts; or, 5th, sifted grains of this material. Mix any one of these with brown sugar, melt and boil (without water) until stiff, press when hot in iron moulds lined inside with paper, chalk, or plaster-of-Paris to prevent adherence and to allow for escape of the gas, the moulds having holes for the same purpose. Heat slowly until a red heat is obtained, at which temperature keep them for some time, then take out and put in upright crucibles with lute; gently raise to a white heat, at which temperature keep them for some time, and then allow them to cool.

The lack of a better carbon than retort carbon di-

1848. Le Molt, 12 219. "Constructing Electric or Galvanic Piles for obtaining Electric Light."

Take one part of coal, coke, or charcoal, three parts of carbon obtained from gas retorts, ground fine, and one of tar; mould and press, dry in the shade, heat gradually in a nearly closed retort until brought to a red heat, at which temperature keep the retort for thirty-six hours, when cool slowly.

Makes the carbon disks used by him in his electric lamp from gas-retort carbon, cut into the right shape, and purified by solution in a mixture of nitric and muriatic acids for twelve hours, afterwards in fluoric acid for twelve hours.

1852. Roberts, 14,198. "Improvements in the production of Electric Currents in obtaining Light," etc.

Mixes five per cent. of lime with materials of electrodes, to increase the brilliancy of the light.

1852. Jackson, 14,830. "Improvements in producing Artificial Light," etc.

Hollows out top of lower carbon and introduces mercury or platinum into the recess.

1853. Binks, 119. "Improvements in producing Electric Light." Provisional protection only.

Subjects lignite to destructive distillation in closed vessels.

Covers metal with tar, pitch, bitumen, asphalt, and resin, or mixtures of finely-pulverized charcoal or lamp-black, with some adhesive material, which on being dried or strongly heated leaves a residue of solid or compact carbon.

Or drills holes in carbon and inserts metal rods, or attaches a veneering of charcoal to metal.

1853. Staite, 634. Boils carbon in oil or other fatty substance, and bakes.

1857. Harrison, 588. "Improvements in obtaining Light by Electricity."

Pieces of metal or other material are placed in gas-retorts, or in tubes connected therewith, for the purpose of receiving a deposit of gas carbon. Or a combination of metal powder and plumbago, or other form of carbon, may be formed into electrodes by compression. Proposes to insert other substances in the powder in order to color the light.

1858. Hunt, 282. "Improvements in Means for Producing the Electric Light."

The residuum from the distillation of tar or pitch is reduced to an impalpable powder, and mixed with tar or other hydrocarbon; the electrodes are then moulded, heated red hot, immersed in tar and again heated, and so on until the required density is obtained.

rected our attention to new processes of manufacture, resulting in the granting of Letters-Patent to Sawyer & Man in January, 1879, for a process believed to be new in physics. In many experiments previously made, incandescent lamps had been charged with an atmosphere of illuminating gas, naphtha, and other hydrocarbon vapors, both at atmospheric pressure and under partial exhaustion, with a view to arresting consumption of the carbon pencil. It was found that the globe soon blackened, and this to an extent commensurate with the amount of the confined gas or vapor, while the carbon pencil became of a bright gray color, but otherwise suffered no change. It thus appeared that the deposit which blackened the globe could not have proceeded from the pencil; and investigation showed that the hydrocarbon atmosphere had been decomposed, the hydrogen set free, and the carbon deposited; and inferentially it appeared that the gray color of the pencil was due to the mechanical combination with it of a portion of the dissociated carbon.

By easy advances the conclusions were reached that if there was any deposit upon the pencil from any given volume of gas, there would be a greater deposit from a greater volume of gas; and that the greater the heat developed in the pencil, and the slower the deposition, the more dense and perfect would be the carbon. These conclusions were subsequently verified. It was found that in a stream of hydrocarbon gas or vapor an imperfect pencil of carbon was rendered perfect, the original points of imperfection, being of proportionately high resistance and heating proportionately to a higher degree than the perfect portions, receiving a deposit which compensated for such imperfection. Thus pencils of carbon of any desired diameter up to one-eighth of an inch, and of a density and homogeneity before unthought-of, and capable of taking a polish like jet, were formed of and upon a mere filamentary conductor. The original filament appeared to be unchanged, the deposit carbon being in the form of a cylinder surrounding it and possible to be broken off from it.

It was found also that the pencil could be as veritably welded or joined to the connecting carbon blocks as two pieces of metal are welded or joined together, and the Sawyer-Man carbon horseshoe, which was perfected and exhibited in the winter of 1878–9, was treated by this process, the ends of the horseshoe being welded to the supporting blocks in order to secure perfect electrical contact.

From obtaining a cylindrical deposit of carbon upon a filament of ordinary carbon, the manufacture of pencils entirely of deposit carbon was attempted. The cylinder was sawed through lengthwise by means of a rapidly-revolving, smooth, thin disk of steel, and the original filament removed. The two portions, semicylindrical in shape, remaining, were then subjected to treatment. The most perfect of all these carbons were prepared by taking sticks of fine willow charcoal, and first saturating the same with syrup and subjecting to heat as in the Carré process, in order to increase their conductivity. The sticks were then divided into pieces one-half an inch in length and three sixty-fourths of an inch in diameter, and placed between carbon-holders for treatment. Heated to extreme incandescence and surrounded by an atmosphere of hydrocarbon, the deposit described immediately formed. The pencil, with shining, rounded ends, was then filed on one side until the original willow was exposed, but leaving the ends of the pencil untouched. The willow being next removed, a pencil of boat shape and remarkable durability was obtained. The Sawyer-Man lamps, as exhibited in New York, were all furnished with carbons of this character, and to the perfection of these boat-shaped, electrically-formed carbons was due their comparative success. To the necessity of frequent renewal, and the time and skill required to produce the carbons, was due the commercial failure of these lamps.

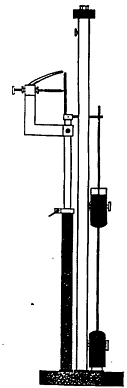

Fig. 41. Carbon-Treating Apparatus.

In preparing long pencils of carbon, allowance must be made for the expansion of the original filament. The Sawyer depositing apparatus (Fig. 41), which holds the filament, is entirely immersed in a hydrocarbon bath. The decomposing current, entering by way of the metallic uprights fixed to a soapstone base, passes through the filament by way of its carbon-clamps. The upper clamp, balanced on a knife-edge, is removable. In this, when removed, one end of the filament is secured and the clamp is then put in position. Next the lower end of the filament is swung between the jaws of the lower fixed clamp, and, this having been tightened, the cam-lever above is thrown up, and the filament thus placed under tension. When the current is applied there ensues violent ebullition of the liquid composing the bath, due to the rapid disengagement of hydrogen; dense volumes of smoke arise, and in from fifteen to thirty seconds the filament is covered with a shell of deposit carbon from one sixty-fourth to one thirty-second of an inch in thickness. Olive-oil is the best hydrocarbon for this treatment. Next in order of efficiency, among common hydrocarbons, are the following:

Refined sperm oil;
Absolute alcohol;
Naphtha and gasoline;
Turpentine.

In using the last-named hydrocarbons, great care must be taken not to overheat the bath, and to see that the filament is wholly immersed before applying the current, otherwise there is danger of fire and explosion.

The carbonizing of live willow twigs, with a view to obtaining a suitable bent carbon, by Sawyer & Man, and the carbonizing of paper and bamboo by Edison, substantially close the account of incandescent carbons. Recently, an attempt to better the texture of the filament has been made by Mr. J. W. Swan, of Newcastle-on-Tyne, who forms it from cotton thread, which is subjected, previous to carbonization, to the action of sulphuric acid in order "to produce the same kind of effect of semi-solution and the welding together of the cellulose fibre as is produced in making vegetable parchment from bibulous paper."

The behavior of carbon at different temperatures is strikingly similar to the behavior of glass at proportionate temperatures, similar results in the latter, however, being attained at much lower temperatures than in the former. As examples the following facts are cited: In hardness and brittleness, glass and homogeneous carbon at ordinary temperatures are substantially alike. Glass, drawn into fine threads, and carbon in filaments, may be bent, and to a certain extent twisted, without breaking. Glass and carbon, heated and twisted or bent, retain the changed form and their normal strength at the point of twisting or bending, upon cooling. Glass moderately heated, and carbon intensely heated, if given a blow, fly into fragments.

Glass and carbon are better conductors of electricity when intensely heated than when at ordinary temperatures.

A ten-inch pencil of carbon, heated to extreme incandescence, expands, under slight tension, to a length of 10¼ inches. Upon cooling it does not return to its original dimensions, but only slightly contracts.

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CHAPTER VI.

NEW FORMS OF LAMPS.

IT was in 1875, after some desultory work, that we first took an active interest in the subject of incandescent lighting. Subsequent years devoted to the perfection of apparatus in connection therewith have greatly augmented the stock of knowledge originally possessed. The theories upon which experimentalists had labored, and the probable causes of their failures, were given careful consideration, and in all matters of doubt the results of practical experiment were made the basis of conclusions.

It did not at first appear that when a carbon conductor is excluded from contact with combining matter, it is nevertheless, in the sense of changing form, destructible; otherwise speaking, the destructibility of all matter subjected to constant and varying tension did not primarily present itself with the convincing force that is born of experience. Many experimenters in incandescent lighting had failed because they had overlooked the fact that nothing is indestructible, or undisintegratable, or unchangeable. Additionally, the Starr-King lamp had failed because there was present in the Toricellian vacuum the vapor of quicksilver, due to heat, with which the carbon entered into chemical combination. Lodyguine obviated an imperfect contact with the carbon conductor by making the luminous section a reduced portion of a large carbon. Lodyguine, Konn, Kosloff, and Bouliguine, recognizing the destructibility of the conductor, sought compensation in self-renewing devices; but their lamps were imperfect in that they did not preserve the carbon from contact with gases with which, at high temperatures, it enters into chemical combination. All of the old lamps, excepting that of Starr-King, were inadequately sealed. All were somewhere attended by conditions calculated to prevent the realizations sought.

To preserve incandescent carbon from chemical change, it must be hermetically sealed in vacuo, or in a globe containing a pure and perfectly dry cyanogen, nitrogen, hydrogen, or hydrocarbon atmosphere. If there is a trace of oxygen or other gas or vapor present, or any third non-gaseous body in condition to come in contact with the carbon, chemical change is the result. Nor can the incandescent carbon establish connection with any metal, for the reason that the carbide of that metal is then formed. Its connections must be with carbon of greater mass, in order that the temperature of the metal contacts may be low and the contacts perfect; and it must itself be pure and also homogeneous, as imperfections in its structure produce consequent points of resistance at which the current concentrates and where disintegration occurs. In the dioxide of carbon (carbonic acid gas), which instantly extinguishes ordinary flame, the incandescent conductor is consumed, not quite so rapidly, but just as surely, as in air. In the monoxide of carbon consumption is certain, though still less rapid. The explanation of this is found in the fact that a current of the heated atmosphere is constantly flowing past the conductor, and the heat of the conductor is so great that the carbonic oxide is decomposed before the two come in contact; and the oxygen thus set free, and having a higher affinity for the carbon of the conductor than for the less heated atom from which it has been dissociated, combines with the former, while the dissociated carbon atom is deposited either upon the interior works of the lamp or upon the inner surface of the enclosing globe; or the oxygen rises in a free state (the carbon being deposited as described), and upon subsequently coming in contact with the incandescent conductor thereupon combines with it to form the monoxide. The monoxide, not the dioxide, is always formed when there is a limited amount of oxygen present. Thus it will be clear that, however slight may be the trace of oxygen in the sealed globe of an electric lamp, and however great in mass the incandescent carbon may be, it is only a question of time when this circular process of chemical dissociation and recombination will entirely destroy the conductor and deposit it upon the interior works and the globe of the lamp. What occurs with oxygen occurs with other substances having an affinity for carbon at high temperatures; and to procure a non-combining atmosphere sufficiently free from impurities involves a very delicate laboratory process. The employment of hydrogen is disadvantageous in these respects, that it necessitates a more powerful current to produce a given light than when the conductor is in vacuo or surrounded by nitrogen, and that, should any leak occur, air sufficient to form a dangerous explosive mixture soon finds access to the globe. For the latter reason an hydrocarbon atmosphere is impracticable, in addition to the fact that the decomposition of the hydrocarbon so blackens the globe as to greatly obscure the light. The incandescent carbon, therefore, can only be practically employed in vacuo, or surrounded by an atmosphere of pure nitrogen, or in a partial or nearly perfect vacuum of hydrogen, nitrogen, cyanogen, or hydrocarbon gas, which last, however, speedily becomes a vacuum of hydrogen, for the reason that the hydrocarbon is decomposed and the hydrogen set free in the lamp.

The idea of protecting carbon from chemical change by enclosing it in a vacuum or a carbon-preservative atmosphere is, as has been shown, by no means new. Atmospheres of nitrogen, hydrogen, and the carbonic oxides, and their vacuums, as well as the ordinary vacuum, have been employed in the laboratory for many years, and are common property of which all experimentalists may avail themselves.*

Next to preserving the carbon from chemical change, the greatest difficulty is found in hermetically sealing the globe of the lamp. The sealing of glass upon platinum is familiarly shown in Geissler vacuo-tubes; and while the degree of skill required for this method of

* The following data, abstracted from the report of Colonel Bolton to the London Society of Telegraph Engineers, March 26, 1879, refer to expired English patents relating to incandescent lighting:

1841. DE MOLEYNS, 9,053. Uses a coil of platinum wire at the base of which is a piece of spongy platinum and into which falls a shower of finely-pulverized boxwood charcoal or plumbago, the whole being enclosed in an exhausted tube.

1845. KING, 10,919. Application of continuous metallic and carbon con-sealing is rare, the Geissler method is undoubtedly as perfect as any yet devised.

In the Edison lamp (Fig. 42) the Geissler method of sealing is employed, the two conductors, A A, leading to the carbon loop, D, being sealed at B B in the glass of the compound globe, E. In order to obtain a perfect connection with the carbon filament its ends are enlarged and clamped in suitable blocks, C. Exhaustion of the air by way of the neck, F, to the one millionth of an atmosphere, leaving in the lamp a portion of oxygen represented by $\frac{1}{1000000}$, follows. The filament originally used by Mr. Edison was prepared by cutting card-board into the desired shape, and carbonizing the same by placing the loops thus formed in layers within an iron box, with intervening layers of tissue-paper, closing the box to exclude oxygen, and raising the whole to red heat in a furnace. Lack of homogeneity in the structure of these carbons subsequently led Mr. Edison to the adoption of carbonized bamboo-wood, which is worked down by successive cutting and scraping until the entire length of the loop between its enlarged ends, which length varies from five to seven inches, is reduced to a uniform cross-section of from one

ductors, intensely heated by the passage of a suitably regulated current of electricity. Uses Toricellian vacuum when carbon is employed. [King was Starr's agent.]

1848. STAITE, 12,212. Uses an iridium or an iridio-platinum wire.

1850. SHEPARD, 13,302. In a ground-glass globe, exhausted, a vertical rod of carbon is, by means of a weight, pushed down into a small carbon cone constituting the terminal.

1852. ROBERTS, 14,198. Complete apparatus for rendering a rod of graphite, coke, or charcoal incandescent in a non-combustible atmosphere.

Placing the carbon in a deoxygenated atmosphere (as hydrogen or nitrogen), rarefied, was patented by Staite in 1846, No. 11,499.

sixty-fourth to one thirty-second of an inch. The delicacy of manipulation of the wood, in order to make the filament uniform in size throughout, renders its cost excessive; but this difficulty, in a measure at least, will probably be overcome. The resistance of the loop when carbonized is from 100 to 300 ohms, and the amount of light obtainable, with safety to the conductor, varies from two to ten candles. Fig. 43 is an illustration of an Edison bamboo filament, full size, before bending and carbonization.

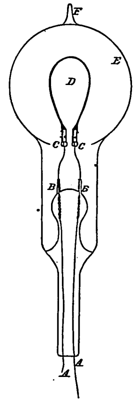

Fig. 42. The Edison Lamp.

In carrying out the Edison method of manufacture a glass bulb (Fig. 44), of the size desired for the enclosing globe of the lamp, is formed, with a supporting neck, extending in one direction, of a diameter sufficient to permit the passage of the illuminating conductor through it. Preferably a piece of tubing, of the size of the neck, has the bulb blown in it. Upon a point on the bulb opposite the centre of the neck is formed a long tube for attachment of the bulb to the air-exhausting apparatus. Upon the end of a smaller piece of tubing a small bulb is formed, and the body of the tube, a little below the bulb, is enlarged for a small space to about the size of the supporting neck of the first bulb. This portion constitutes the loop-supporting part, platinum wires, terminating in clamps for holding the loop, being passed through it and hermetically sealed therein. After the filament is in place, as

Fig. 43. Bamboo Filament.

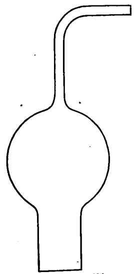

Fig. 44. Edison Outer Globe.

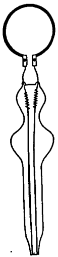

Fig. 45. Inner Globe and Works.

shown in Fig. 45, the small tube is passed up into the bulb of the large tube until its further passage is stopped

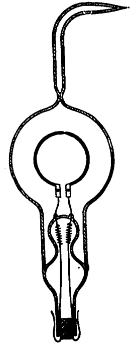

Fig. 46. Globes joined together.

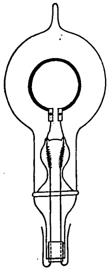

Fig. 47. Lamp Sealed.

by the neck of the latter, when the two are sealed together by fusion, and appear as shown in Fig. 46.

The mechanical construction of the lamp being now complete, it is attached to the vacuum-pump by the neck before-mentioned, and when a proper degree of exhaustion has been attained, the end of the tube is softened and sealed by heat, after which the lamp is removed from the pump. Finally, the tube is softened and sealed near its point of juncture with the globe, when the portion remaining above is broken off and the neck again softened and sealed immediately above the sealing before made at the point of juncture. Fig. 47 shows the completed lamp.

The Maxim lamp (Fig. 48), recently exhibited in New York, differs from Mr. Edison's in no essential particular. The Geissler method of sealing is employed, and the carbon filament, manufactured from card-board, is made in the form of a double loop, closely resembling the letter M. Thus prepared, the light obtainable is substantially the same as that from the Edison lamp. When the filament is treated by immersion in hydrocarbon by the process of depositing already described, its section is enlarged and improved, and the light then obtainable is from 10 to 30 candles.

Before sealing his lamp, Mr. Maxim fills the globe with the vapor of gasoline, to the exclusion of all air, and finally exhausts by means of the vacuum-pump.*

Run at a power of eight candles, in a nearly perfect

* An erroneous impression, in regard to the Maxim lamp, due to the employment of gasoline in the process of exhaustion, is that it is a self-renewing device—*i.e.*, that whenever consumption or disintegration occurs, the filament is repaired by an ever present supply of hydrocarbon. The reverse is the case. When ready for use the globe contains a trace of gasoline vapor, and this is almost immediately decomposed, setting the hydrogen free, and leaving present a trace of hydrogen merely.

vacuum, the life-time of filamentary carbons is from ten to one hundred hours.

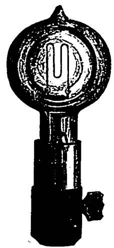

Fig. 48. The Maxim Lamp.

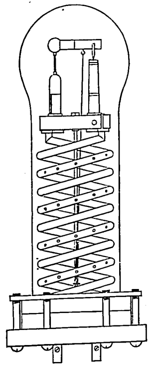

Fig. 49. The Sawyer-Man Lamp.

The Sawyer-Man system of lighting was exhibited in New York in 1878. Fig. 49 is an illustration of the first device of these experimentalists to which publicity was given.

In this lamp the enclosing globe was provided with a flange constituting an integral part of the globe, and a disk of glass perforated with two small holes was accurately ground to fit the same. The ground surfaces were coated with fir balsam, and the globe and stopper strongly clamped together by means of bolts passing through an elastic flange below the stopper, and a metallic flange bearing upon the glass flange. Through the holes in the stopper passed the diminished ends of two stop-cocks, whose joints were made perfect by drawing their shoulders powerfully down upon paper washers first thoroughly impregnated with balsam. Subsequently, melted sealing-wax was poured around the whole of the base. By this means very perfect joints were secured, and to retain them so it was only necessary to prevent undue heating of the parts. Therefore, the conductors leading from the outside stop-cock connections to the illuminating part of the lamp were given considerable length and large radiating surface. An insulating diaphragm supported the upper works.

The incandescent carbon pencil, one-half inch in length, and varying in different lamps from one thirty-second to one-twelfth of an inch in diameter, was held in small carbon blocks let into larger blocks, one of which was fixed in the lower standard, and the other in a connecting arm, which, in order to allow for expansion and contraction of the pencil without friction, was supported upon a knife-edge bearing. This connecting-arm was held in place by a coiled spring. The spiral conductors consisted of tubes, one of which was provided with openings along its length, and each connecting with a stop-cock. A lump of metallic sodium or potassium as an absorbent of oxygen; and its oxide, when formed, as an absorbent of carbonic acid gas, was placed in the lamp. To charge the lamp, a stream of nitrogen was caused to flow through one of the tubes to the upper part of the globe, escaping by way of the openings in the other tube. Carbons of a

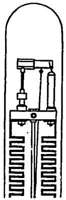

Fig. 50. Lamp with fluted Conductors.

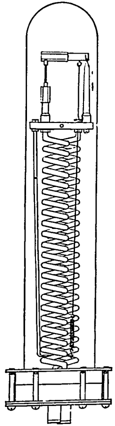

Fig. 51. Perfected Lamp.

density before unattained were employed in this lamp; and although, through imperfect contacts and a faulty atmosphere, many of the lamps failed to last more than a few hours, some of them were used daily for several weeks without exhibiting marked change. In the construction of the lamp, it was found essential to round the ends of the carbon pencil, and to make a tapering cavity in the small connecting-blocks, which were firmly set in the larger blocks. The final sealing of the lamp was effected by soldering the stop-cocks. Fig. 50 represents the lamp in another form, with radiators of copper ribbon to prevent conduction of heat to the base; and in Fig. 51 is shown the perfected lamp, with small spiral conductors, in which the soap-stone was replaced by a metallic diaphragm.

The Sawyer-Man experiments were of an extensive and diversified character, and among the earliest attempts to obtain a practicable lamp was the including of an arch or loop of carbon in the circuit of the radiators (Fig. 52).

This carbon loop was originally employed in March, 1878, a rod of retort-carbon being turned true in a lathe and bored out to form a tube; from this, thin flanges were cut, and after being clamped between carbon washers, the upper half was left standing and the lower part broken out. It was not until the following winter that the carbonizing of different substances in the form of a loop, and especially twigs of fine willow, was attempted, with varying results. A year later Mr. Edison greatly improved the manufacture of these loops by processes much better calculated to attain the end desired than those employed by Sawyer & Man, whose success in this direction was limited.

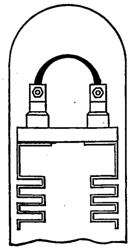

Fig. 52. The Horseshoe Lamp.

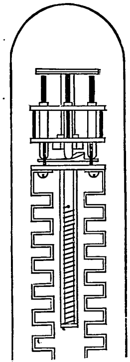

Fig. 53. Self-renewing Lamp.

The fact appearing that it is only a question of a brief period of time when a carbon loop or pencil subjected to the action of powerful currents will suffer disintegration, it is clear that some means of renewing the incandescent conductor of any lamp must be provided; and this renewal must be accomplished without destroying the lamp. To replace a Sawyer-Man carbon required a workman's time from two to three hours, and the recharging of the lamp with absolutely pure nitrogen cost about seventy cents, without taking into consideration the cost of the carbon. It was therefore an impracticable lamp. To obviate frequent renewal the first Sawyer feeding-lamp (Fig. 53) was devised.

In this lamp several short carbon pencils were held by copper rods, as in the Konn lamp, and as fast as one was consumed or disintegrated, a cam, rotated by a coiled spring, forced another carbon into contact with the block above. Thus a very durable apparatus was obtained, but by no means a successful one; for when the lamp is properly charged, or exhausted, chemical change in the carbon is no longer to be considered, and the point of disintegration is generally the upper point of contact. In this form of self-renewing device we do not, therefore, obtain the full value of the pencil, which ordinarily drops out when it is only partially or even very slightly disintegrated.

A long pencil, fed through an elastic contact, was the originally-held conception, and this was eventually resorted to in the lamp (Fig. 54) designed early in the year 1879. In this lamp, by means of an electro-magnetic switch, an electro-magnet, operating through the glass stopper of the globe, was caused to feed upward between elastic contacts, as fast as disintegration occurred, a long carbon pencil travelling in a metallic tube.

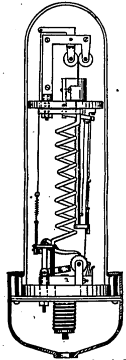

Fig. 54. Electro-Magnetic Self-Renewing Lamp.

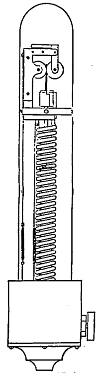

Fig. 55. Hand-Feeder.

Imperfections in the operation of electro-magnetic feeding devices led to the designing of another lamp curred, a long carbon pencil travelling in a metallic tube.

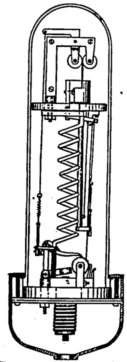

Fig. 54. Electro-Magnetic Self-Renewing Lamp.

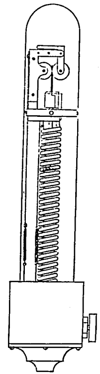

Fig. 55. Hand-Feeder.

Imperfections in the operation of electro-magnetic feeding devices led to the designing of another lamp

(Fig. 55), in which the pencil was fed upward from the outside, when necessary, or drawn downward from its connection with the upper contact-rollers when extinguishment of the light was desired. With lamps of this type the first private residence, it is believed, in the world, was practically illuminated by electricity in the winter of 1879–80 and during the following month of March.* The halls, parlors, and upper chambers of a New York dwelling-house were supplied with electricity, through a single conductor, by a generator located a block and a half distant. Each light was turned on or off, or graduated to any desired degree of intensity, independently of other lights. The internal resistance of each lamp was about .25 ohm.†

* No. 226 West Fifty-fourth Street, New York City.

† Since this was written our attention has been called to the fact that at Salem, Mass., during the month of July, 1859, Professor Farmer lighted his parlor by two incandescent platinum lamps. In a letter to the Salem *Observer* of November 2, 1878, Professor Farmer adds: "And this electric light was subdivided, too! This was nineteen years ago, and it was undoubtedly the first dwelling-house ever lighted by electricity. A galvanic battery of some three dozen six-gallon jars was placed in the cellar of the house, and it furnished the electric current, which was conveyed by suitable conducting-wires to the mantelpiece of the parlor. Either lamp could be lighted at pleasure, or both at once, by simply turning a little button to the right for a light, to the left for a dark." It is barely possible that Professor Farmer's memory may be in error in respect of dividing the current. Whether it would have been more natural for him to divide the battery into two separate parts of some one and a half dozen jars each, and operate one lamp from each part, than to go to the trouble of arranging resistances and complicated switches in order to operate so small a number of lamps as two from a single battery in close proximity to them. is not considered; but it would have been more satisfactory if, in making the above claim, Professor Farmer had stated in what manner a button was arranged so as to light both lamps at once, or to light either one separately, by the one operation of turning the button to the right.

CHAPTER VII.

NEW FORMS OF LAMPS (CONTINUED).

WE may now be supposed to have arrived at an adequate conception of the principles underlying the various forms of incandescent lamps. We have seen that an incandescent carbon, however completely isolated from gases with which at high temperatures it enters into chemical combination, is a destructible mass of matter. We have, perhaps, reached the conclusion that means for its renewal must be provided, and that this renewal must not be frequent, and that it must be cheaply accomplished. The lamp, furthermore, must be cheaply and hermetically sealed, and readily recharged with a carbon-preservative atmosphere, or exhausted of such atmosphere, or exhausted of atmospheric air.

The new Sawyer lamp, exhibited in New York, and at the Franklin Institute in Philadelphia within the past few weeks, is designed to meet the requirements mentioned. The illustration (Fig. 56) shows this lamp in its perfected form.

In Fig. 57 the lamp is shown with the interior works and base apart from the enclosing globe. Upon a thin metallic base is fixed one of the upright metallic conductors leading to the top of the lamp. The other conductor is fixed to an insulated bolt passing downward through the centre of the base. These conductors are of steel, in order to prevent rapid conduction of heat to the base, and are formed as shown in order that they may be readily stamped from sheet-metal and pressed into the required shape. By means of a copper plunger attached to a wire running over a winding-drum at the base of the lamp, in which drum an ordinary watch-spring, furnishing the motive power, is coiled, a long pencil of carbon in the plunger-tube is automatically fed upward through the lower elastic carbon-contacts to a connection with the upper perforated carbon-block. Thus the pencil is constantly forced to a bearing against the upper carbon-block until entirely disintegrated; and when entire disintegration has occurred the plunger closes the circuit of the lamp. As heretofore explained, the point at which disintegration mainly takes place is the upper point of contact; and as, when the pencil is protected from combining matter, this disintegration amounts to between the one-hundredth and the fiftieth part of an inch for every hour the lamp is run, and as the pencil is eight inches in length, it follows that the useful lifetime of the carbon is from 400

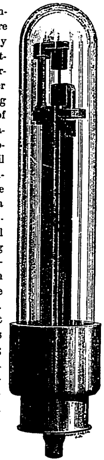

Fig. 56. The Perfected Sawyer Lamp.

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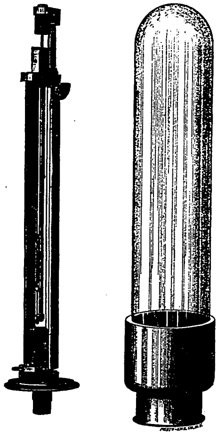

Fig. 57. The Sawyer Lamp, apart.

to 800 hours, equivalent to four hours' daily use for from 100 to 200 days. In this calculation it is assumed that the intensity of the light shall not exceed that of two good five-foot gas-burners, or at most thirty candle-power. Run at a higher intensity the durability of the pencil is diminished.

The glass globe of the lamp has no direct connection with the base supporting the lamp mechanism. In a thin, spun-metal, open cup, amounting practically to a short tube, the globe is sealed by heating the cup and the glass, and pouring into the annular space between the glass and cup a sealing compound which is elastic at all ordinary temperatures, adheres to both glass and metal, and does not soften at temperatures attained in the lamp. The sealing space is two inches deep and one-quarter inch wide, and the sealing compound substantially as homogeneous as glass; hence the element of leakage at this point may be disregarded.

In order to place the carbon pencil in the lamp, the upper carbon-block is carried to one side by moving the sustaining-arm on the standard connected with the insulated steel upright, and space is made for the pencil by moving the plunger to the bottom of the tube and thus unwinding the wire on the drum. The lower carbon clamping-blocks, whose mutual pressure is sustained by a spiral spring, placed lower down in the lamp so as to prevent its undue heating, are then separated, and the pencil of carbon is dropped into the tube. Finally, the upper carbon-block is moved back into the position shown, when the lower carbon-clamps and the winding-drum are released, and the pencil is brought to a bearing in a central opening through the upper carbon-block. The circuit is by way of an insulated wire enclosed in the bracket to the central insulated bolt, one of the upright steel conductors, and the upper carbon-block; and downward, through the pencil, as far as the lower clamping-blocks, and the other upright steel conductor, to the base of the lamp and the bracket. To connect a lamp in circuit it is therefore necessary to fix it to the ordinary nipple-thread of a gas-fixture, the two contacts thus being established.

The peculiar shaping and general design of the parts of the lamp are such as to facilitate and cheapen their manufacture. The carbon-blocks are formed in moulds. To prevent oxidization from handling and exposure, all of the parts are nickel-plated. All of the metallic parts above the upright steel conductors, and the pencil-tube, are of pure copper. The leading wires of the winding-drum and the coiled clamping-spring are of steel. All of the parts at the base of the lamp, excepting the screws, are of brass. A stop-cock, or a single opening, through the base, closed by a short brass screw, is employed in the charging of the lamp.

When the carbon pencil has been introduced, the glass globe, sealed in the brass spun cup, is lowered over the works and fits closely to the shoulder turned on the base. The workman then passes a soldering-tool around the junction of the cup with the base, and this joint is hermetically sealed. To facilitate the soldering, as well as to economize material and prevent excessive heating of the sealing compound between the globe and the cup, the base as well as the cup is made only thick enough to be substantial. To renew the pencil, when entirely destroyed, the junction of the cup and base is rotated in the flame of a Bunsen burner, when the solder softens and the globe and cup are removed. To replace the pencil, and resolder the connection of the cup and base, is the work of a few minutes. The globe, once sealed in the cup, is not again disturbed. At each renewal of the carbon it is of course necessary to refill the globe with nitrogen, the stop-cock or screw, closing the charging opening, being also finally soldered, in order to ensure hermetical sealing of the lamp throughout.

All insulations above the base are of mica, in order that the heat of the upper works may not disengage dust or vapors, whose action upon the incandescent pencil would be deleterious. The diameter of the globe is 2 inches and its length 10 inches. Lamps have been constructed of all sizes down to one having a globe ½ inch in diameter and 2½ inches in length, but the dimensions adopted have been found to be the best in practice. The shape or design of the globe is inconsequential, which may also be said of the general structure of the lamp, except in so far as questions of economy are concerned.

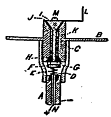

Fig. 58. Bracket-Connections.

The method of sealing the insulated central bolt, and establishing the external connections of the lamp, is shown in Fig. 58, in which A is the arm of any gas-fixture, and B the base of the lamp. The upright conductor L is fastened to the bolt I by a screw, M. In a conical cavity leading to the long bolt-hole is placed a conical fibre washer, J. In passing through this hole the bolt does not touch its sides, but while the base is hot the annular space around the bolt is filled with the same

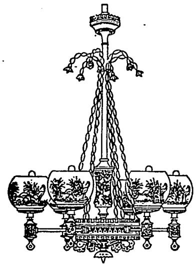

Fig. 59. Chandelier of Lamps.

cement, K, as is employed in sealing the globe to its cup, and the nut G, bearing upon the conical fibre washer H, is firmly screwed upon the lower end of the bolt. The cap C is then screwed on to the projection from the base. In a cavity in the end of the bracket is sunk an insulating washer, D, through which passes the insulated wire N, screwed into contact-nut F. The coiled spring E gives elasticity to the lower point of contact, so that the lamp may be turned into any position. The long, narrow, annular space around the bolt I, filled with homogeneous cement adhering perfectly to the metal, ensures the hermetical sealing of this last and most difficult joint to seal.

In Fig. 59 the arrangement of a chandelier system of lamps is illustrated.

The luminous intensity of the new Sawyer lamp, which is the same, under like circumstances, as that of all the Sawyer-Man, Konn, Kosloff, Bouliguine, and other Sawyer lamps, is from two to three ordinary five-foot gas-burners. What is meant by this is the intensity of light produced at which it is considered safe to run the lamp continuously, when it is desired that renewal of the carbon pencil shall not be necessary more frequently than once in from six months to a year. Doing two hundred hours' actual work the lamp may be run at an intensity of from 100 to 200 candles. Doing fifty hours' work it may be run at an intensity of from 200 to 600 candles.

Numerous measurements of the power of the light have been made, but the most critical, conducted by Mr. Edgerton, with a Sugg photometer, accord the small-power lamp a luminous intensity of 27.4 candles.*

* The following certificate by Mr. Edgerton, referring to the perfected Sawyer-Man lamp, and which applies as well to all pencil lamps in which a pencil of the same length and cross-section is rendered incandescent, contains some valuable suggestions in view of the candle-power claimed by gas corporations and that shown at their laboratories :

In order to obtain, when desired, greater illuminating power, a larger lamp (Fig. 60) has been devised.

The dimensions of this lamp are 4 × 16 inches, and its luminous intensity is from 100 to 1,000 candles, according to the length of pencil brought to incandescence and the volume of current supplied. At the Franklin Institute, in Philadelphia, on November 9, 1880, a single large lamp served to illuminate the lecture-hall with the brilliancy of mid-day. There is no difference in construction between this lamp and the small lamp, excepting that in the large lamp the upright conductors are made of round steel rods, which is sometimes true of the small lamps. In the large lamp the carbon pencil is 12 inches in length and $\frac{3}{32}$ of an inch in diameter, with an exposed section of $1\frac{1}{4}$ inches; while in the small lamp it is $\frac{1}{16}$ inch in diameter, with an exposed sec-

NEW YORK, November 8, 1878.

The illuminating power of one of the Sawyer-Man lamps, tested by me this day, gave, in comparison with a standard sixteen-candle burner, a power of 1.714 burners, or 27.42 standard sperm candles.

(Signed) H. H. EDGERTON.

In order to compare the light with that afforded by ordinary gas-burners, the different burners in ordinary use, with coal gas, may be rated about as follows, for a rate of five cubic feet per hour consumption:

Ordinary fish-tail, Scotch tip, about 5 candles.

Young America, brass fish-tail, 8 candles.

Gleason, noiseless Argand, 11 candles.

Lava tip (excavated head), 12 to 13 candles.

A very large flame, burning at a rate of 8 or 9 cubic feet, will give a *pro-rata* light of about 15 candles for 5 cubic feet.

The above is based upon gas made from ordinary Pittsburgh coal. Mixtures of cannel or naphtha improve the quality according to the amount used. (Signed) H. H. EDGERTON.

London is supplied with gas of 16 candle-power per 5-foot burner. The Liverpool street-lamps give a light at the rate of 16 candles per 5 cubic feet with 4 cubic feet consumption.

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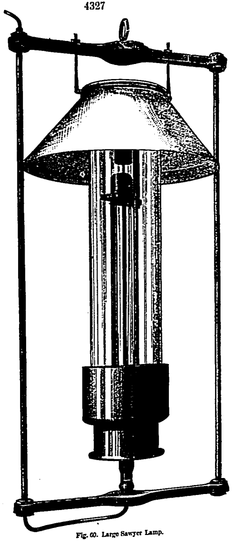


Fig. 60. Large Sawyer Lamp.

tion of ½ inch. Owing to the greater intensity at which the large lamp is run, the working duration of the pencil, when the globe is perfectly charged with nitrogen, is about 200 hours. The cost of renewal (that of the carbon and nitrogen elements) is largely in excess of the cost of renewal in the small lamps, and varies from 25 to 30 cents per lamp.

The permanent, elastic closing of the Sawyer globe in its metallic containing-cup is the only method yet devised that affords the necessary hermetical sealing, excepting that of Geissler, which is employed by Mr. Edison. Many experimentalists in this line have employed hydraulic joints: Kosloff employed a bath of olive-oil around the joints; Guest and others have employed quicksilver; our own experiments, of a similar character, have been confined to viscous hydrocarbons. But all these devices are inadequate; for while they may truly prevent the entrance of air, in-leakage of the mobile sealing substance itself cannot be prevented, and thus there is introduced into the lamp an element which will either destroy the carbon or so blacken the globe as to obscure the light. Every part of the lamp must be perfectly clean; and, indeed, the delicacy of manipulation necessary in the construction of incandescent lamps cannot be appreciated by any one not familiar with the subject, and who only observes the facility with which the skilled workman performs his duties.

Operating upon the principle of decomposition of hydrocarbon and the deposit of the carbon atom upon an incandescent filament, we have constructed an open-air lamp of a somewhat novel description (Fig. 61).

Upon a brass wheel are mounted six carbon horseshoes, all the negative poles of which are connected together on the wheel, and the positive poles of each op-

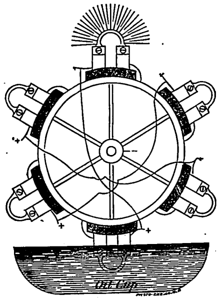


Fig. 61. The Sawyer Open-Air Lamp.

posite pair of which are connected together and to opposite segments of a commutator of six segments. The current is directed by a contact-brush and the framework of the apparatus, and, dividing, passes through the uppermost and lowermost carbons at the same time.

The uppermost carbon burns in the air at intense incandescence, while the lowermost carbon, immersed in oil in a suitable containing vessel, becomes coated with deposit carbon. As the uppermost carbon consumes and decreases in size the intensity of the light does not increase, for the increase in the size of the lowermost carbon balances the effect of the current above by increasing the supply below and decreasing the supply above. By means of intermittently-operating clock-work, before disruption of the uppermost carbon occurs, the next pair of carbons is brought into position; and the operations described continuing, there is presented the anomaly of an incandescent open-air lamp of indefinite duration, in which, by one operation, light is produced and carbon manufactured, so long as the supply of oil is maintained. The objection to this lamp is that one-half of the current is always employed in renewing wasted carbon.

Light by incandescence is considerably more costly than light by the voltaic arc, when the volume of light obtainable is the sole consideration. The same expenditure of power that will produce a light of 1,000 candles by the voltaic arc will not produce, on the average, more than one-half or one-third as much light by incandescence in a divided circuit. It should not, however, be forgotten that the power of any light decreases as the square of the distance from it, and that one-fourth of the light of the arc distributed at four or five appropriate points, thus reducing the power of each light to one-sixteenth of that of the voltaic arc, will give substantially as good a general illumination as the voltaic arc.

The incandescent light is whatever may be desired. The voltaic-arc light is necessarily a powerful one. The objection to it, if used without a shade, is its great intensity and ghastly effects, and in order to obviate these defects glass shades of more or less opacity are employed, which, according to practical tests, involve a wastage in light of—

With ground glass, 30 per cent.;
With thin opal glass, 40 per cent.;
With thick opal glass, 60 per cent.

In some cases the wastage is nearly, if not quite, 75 per cent.

The loss of light involved in the "toning down" of the arc is clearly set forth in confirmed tests of the power of the Jablochkoff candle, now extensively used in England and France. The actual power of this light is 453 standard candles, but owing to obscuration, occasioned by the opalescent globes with which it is necessary to surround the light, it is found that only 43 per cent. of its full power is available. In incandescent lighting no such loss occurs, and the cost of the carbon consumed, which in voltaic-arc lamps amounts to from four to six cents per hour per 2,000 candles' light, is reduced to an inconsequential figure.

In concluding this chapter, it is proper to remark that the light of an incandescent carbon is very unlike that of the voltaic arc. Its characteristics are the characteristics of daylight; and this is true to such an extent that, from its soft and agreeable nature and absence of glaring effects, the degree of illumination afforded is not always readily appreciated.

Complainant's Exhibit "Du Moncel La Lumiere Electrique, Articles Nos. 3 and 4." February 28, 1890. S. M. H., Exr.

(Translation.)

LA LUMIERE ELECTRIQUE.

Vol. 5, No. 53, pp. 1 to 9.

Paris, Oct. 1st, 1881.

THE ELECTRIC INCANDESCENT LAMPS.

In a preceding article we have shown in what cases this system of electric lighting was specially applicable, and we have seen that now, thanks to the important improvements which have been lately made in it, it can be employed for the lighting of low intensity in the interior of houses; we have also seen that several mansions in England have been lighted in this manner, and that a certain number of houses in the City of New York have made arrangements with the lighting company of Mr. Edison.

Since the appearance of these lamps a large number of systems of the same class have been brought forward by different inventors, and, without mentioning those well known of Messrs. Edison, Swan, Maxim, Lane-Fox, Sawyer, we know of a lot (une quinzane) of inventions which relate more or less directly to it.

It consequently appears to us opportune to enter into the details of this mode of lighting, for which, until now, we have not had in Europe a great interest for diverse reasons which we have enumerated in various articles published in this journal in the beginning of the year 1880, of which, however, the principal reason was the considerable expense relative to the motive power which was required for a light of given intensity.

It should, in fact, be remembered that the luminous power of an incandescent body increases in a much more rapid ratio than the heat intensity. Now, although for this reason, that incandescent lamps permit of a larger division of the electric light, there must be a loss by the feebleness of the radiant power, which results from it.

Nevertheless, the satisfactory results which have of late been obtained, oblige us to review these systems of lighting, and we will commence, naturally, with that of Mr. Edison, which is the best known (qui a fait de bruit) and which has attracted attention to this method of producing lighting by electricity.

EDISON'S SYSTEM OF ELECTRIC LIGHTING.

The incandescent system was first represented by lamps made from an incandescent platinum wire, and the interesting experiments, made in 1859 by M. de Changy, should be recollected; but the practical workings of this system were not satisfactory, principally because of the disaggregation and partial fusion of the wire, and in spite of the numerous improvements brought to bear on this sytem by Mr. Edison, who, by one of the most ingenious of processes, had rendered them more infusible and harder, still they had to be absolutely rejected—at least for ordinary lamps. Then it was suggested to employ carbon which, if not allowed to burn, is infusible in the highest heat developed in the lamps, and different arrangements of apparatus were put together at various times by King, Lodyguine, Bouliguine, Swan, Sawyer, &c., some avoiding combustion by enclosing the lamps in receptacles where a vacuum had been obtained, others by filling these receptacles with gases unfit for combustion, as nitrogen or oxide of carbon, or simply by leaving the air shut up in the receptacle to be vitiated by an incipient combustion.

All these attempts had but partially succeeded, to say nothing more, when, in 1879, the new incandescent carbon lamp of Mr. Edison was announced, and many *savants*, and myself in particular, doubted the exactness of the allegations which came to us from America.

The carbonized paper horse-shoe appeared incapable of resisting mechanical shocks, and of supporting incandescence for any length of time. At this epoch Mr. Swan himself said that up to that time he had not been able to obtain any very satisfactory results by an analogous disposition of the incandescent organ.

Mr. Edison, however, was not abashed, and in spite of the lively opposition made to his lamps, in spite of the bitter polemic of which he was the object, he did not cease to perfect it for practical purposes, and has at last produced lamps, which we have seen at the Exposition, and which can be admired by all the world for their perfect steadiness. These lamp, to the number of 160, light the two salons reserved for the discoveries of the ingenious American inventor, and we shall see still more important results upon the installation of the great machine which is expected from America.

As at present made, these lamps are sufficiently solid and can last a long time. The originally fragile carbon has become extremely elastic and hard and of such attenuation that it can be well compared in size to a horse-hair. By a cleverly combined system of fastening, the platinum conducting wires are not exposed to be cut, and they are so sealed in the glass receiver that their change of volume under the action of heat does not endanger the perfection of the vacuum. By the way the carbons are treated when the vacuum is made in the globe, the bubbles enclosed in their pores and which, in escaping, disaggregate the surface, are evacuated before closing the lamp, and at the same time the filament of carbon acquires a peculiar density and hardness, as was the case with the platinum wires. To obtain this result the carbonized filament must be brought into incandescence while the vacuum is being made. The very nature of the substance of vegetable origin employed in its fabrication has been modified.

Fibres of bamboo are now used instead of the paper originally employed. These are carbonized by a certain process, and the successive transformation of these fibres into carbon filaments may be followed in several collections to be seen at Mr. Edison's exposition, and which will gratify the curious and are worthy of study.

According to Mr. Batchelor and Mr. O. A. Moses, co-laborers of Mr. Edison, and who represent him at the exposition, the resistance of these filaments is 125 ohms when brought up to an incandescence corresponding to 16 candles, but it can vary according to the luminous power desired of the lamps, for it can be distributed between two lamps, whose filaments are correspondingly more or less long. Their extremities, which are enlarged, are pressed in a kind of pincer which terminates the platinum conductors, and which are soldered by an electrolyically deposited copper. Fig. 1 represents the actual arrangement of these lamps. Their duration, from what I have been assured, is long enough; however, they must wear out. Although most of them may have served for 1,200 hours, the question may be asked whether a lamp capable of deterioration may be considered a practical thing, but if it is considered that this lamp can be furnished for 30 cents, that the adjustment on its support cannot be any simpler than it is, which is evident on inspection, it is easily seen that there is no more trouble to replace one of them than to renew a broken lamp shade.

What constitutes Mr. Edison's system is not alone his lamps, it is the totality of the arrangements referring to them, and which have attained such a degree of simplicity that henceforth nothing remains to be desired in practice. Generating machines, distributing of circuits, installation, indicating and regulating apparatus, meters for measuring the amount of current employed are all combined for immediate application. As we have said, this application is about being made in a part of the City of New York, where a great number of houses are to be lighted by this system by means of a subterranean distribution from a central station, from which, also, motor power will be distributed to the houses.

This central station will be provided with twelve steam engines of 150 horse-power each, actuating dynamo-electric machines, each of which will be capable to supply, it is said, 2,400 lamps of 8 candle power.

The current furnished to these lamps comes through a branch taken before these houses from the large sized conductors laid in the streets. These deviations bring the poles of the generator into each house, where the lamp wires can be brought in connection with them, thus rendering each house independent of any other, both for a supply of light and motive power.

When it is considered that in the system of distribution adopted by Mr. Edison, the total resistance of the exterior circuit is extremely reduced, and that with 2,400 lamps it is only $\frac{125}{2400}$, say about .026 of an ohm, it can be seen that a very feeble resistance should be given to the generating machine; so that its first arrangement has been modified. To begin with: The field magnets were arranged on a derivation taken from the commutator, putting it into the induced circuit as in Wheatstone's and Siemens' system. Then the armature was arranged on Siemens' principle so that the wire consisted of bars of copper. These bars lie close to each other around the cylinder which forms the armature, and they generate the current. Their extremities correspond to discs of copper (at right angles to them) laid one against the other at the ends of the cylinder, and insulated from each other. Each bar is fastened to its corresponding discs in such a way as to form a single circuit enveloping the cylinder longitudinally, and which is made perfect through the bars coupled two and two with the commutator blocks (made after the Grammes pattern). Figs. 2 and 3 give an idea of this new arrangement. The center of the cylinder itself is occupied outside of the rotating axle by a cylinder of wood, which in its turn is surrounded by a thick tube made of a series of very thin discs of iron, separated from each other by tissue paper. This arrangement facilitates the rapid changes of polarity in the plates. This tube is terminated at its two extremities by two thick clamping discs which are made to compress the others laterally, and the copper discs of the working coil occupy the two compartments at the extremities of the cylinder as seen in Fig. 2. Under such conditions as these the resistance of the generator is small, and permits of great subdivision of the current in multiple arc; nor is there any insulation to be burned, and it is even possible, in case of the deterioration of the bars, to renew them easily, for they are simply screwed against the copper discs corresponding to them. In the new disposition adopted by Mr. Edison, the field magnets lies horizontal instead of being placed in the vertical.

Fig. 4 represents the whole machine as now actually working in the *Palais de l'Industrie.*

We have described the generating machine before completing the description of the system of distribution of the current, because we ought to speak of the system of control used in making the current uniform when its intensity has been modified by a variation in its distribution; that is to say, following after a variation resulting from the unexpected suppression of a certain number of lamps in a part of the system. The necessities of this system are easily understood, if we consider that this suppression can lead to a greater or less increase in the intensity of the current feeding the remaining lamps.

In France several systems have been devised to obtain an automatic regulation, but in America, it seems, it is preferred to effect this by the intermediation of an appropriate controlling agent.

In this system, whose general arrangement we see in Fig. 5, the current which feeds the lamps, furnishes a deviation at the machine *b b*, which enters an electric dynamometer, after having gone through a resistance of 180,000 ohms. The electro-motive force should be about 110 volts, and a difference of one volt should correspond on the scale of the indicating apparatus to three divisions; consequently, for each observed increase of intensity a resistance capable of compensating for it should be introduced into the circuit. Mr. Edison has established a circular commutator *c*, with bobbins

of different resistance, which permits of an increase of resistance, not in the lamp curcuit, which would lead to a loss of work, but in the circuit of the field magnets, which weakens their action on the working coil. From the central station also the condition of the current affecting the lamps can be controlled by means of a testing photometer, which enables us to see how much the intensity of the current must be diminished or increased to correspond to a given luminous intensity. For this purpose the photometer is mounted on a little railroad placed in a dark chamber; under and in front of it is placed a scale arbitrarily divided so as to indicate immediately the candle-power furnished by the current in its normal condition. The left side of Fig. 5 indicates the manner of arrangement of the testing bench, with the explanatory table at the bottom of the figure. Fig. 6 shows it in perspective. The manner in which derivations are taken on the principal conductors merits especial mention. The conductors are composed of two rods of copper of hemi-cylindrical form, flat on one side and round on the other, which are enveloped in cylinders of insulating material, contained in small wrought iron pipes, which are buried under the streets. To take a derivation the cable is laid bare at the spot where the branch circuit is to be established. The two conducting rods (coming from the main conductors) are cut and bent outwards and introduced into a clamp where they are soldered to the house wires, as shown in Fig. 7; but in order that no harm can be done by too strong currents, one of these communications is made by intercalating a lead wire in the branch circuit, shown at the bottom of the figure, and which, by its fusion, interrupts the circuit. This is what is called in America a "cut off;" and in this way it prevents deterioriation. The box is then hermetically closed and covered with an insulating coating. In the figure the branch wires are shown double, but it is evident that they could be single.

We said that all arrangements had been made to make the system a perfectly practical one, and of that we will soon be able to judge. Let us examine first how the lamp supports and the lamps themselves are disposed. As has been seen, they are formed of glass globes of ovoid form, cemented into copper sleeves by means of plaster and screwed into cylindrical cavities terminating the supports. These are a kind of arm which can be adapted to brackets or chandeliers, or be arranged around the walls. In the last case, the arm, as is shown in Fig. 8, carries two articulations, A and B, and commutations are made by two plates of the hinges which are insulated, and in whose circular part two springs press, as seen in Figs. 9 and 10. Connections of the conductors with the lamp, as we have indicated above, are made by a lead wire (cut off) which may melt and interrupt the circuit in case a too great quantity of current should endanger the lamp.

In these brackets, as in three branch chandeliers, represented in Fig. 11, keys have been introduced which allow the extinction of the lamps separately or together, without causing any spark at the point of rupture or any danger of fire. The movement of the key *a*, as shown in Fig. 12, breaks the contact by means of a conical stopper which terminates the screw of the key, and which when separated from the two plates, through which the current passes when the stopper is in contact with them, breaks the circuit at the points and on a surface of sufficient extent to greatly diminish the spark at the point of rupture.

The lighting of the two salons of Mr. Edison at the Exposition is done by 16 small chandeliers like the above, two grand crystal chandeliers and 80 brackets. Fig. 12 represents one of these chandeliers.

The effect is very beautiful, the steadiness being as complete as could be desired, and if, as I have been assured, the price of this kind of illumination is lower, light for light, than gas, it may be considered that the problem is on the eve of solution, for Edison's system of electric lighting is placed in the same condition as that of gas. He avoids the presence of machines in separate houses, which always are in the way, and

which, by their very nature, require care and management not to be obtained from ordinary servants.

As a complement to his system, Mr. Edison has constructed portable chandeliers, represented in Fig. 13, and a current regulator, shown in Figs. 14 and 15, which permits of reducing the light in any desired proportion. It is a carbon rheostat, composed of carbon pencils of different sections, which, as the current passes through one or the other, allows any desired intensity. The apparatus is enveloped in a cylindrical cover, pierced with holes to allow of the escape of heat, and surmounted by a lamp which indicates to the eye the desired degree of luminosity. It is worked by a disc, shown separated in the lower part of Fig. 14, which can be turned so as to bring a contact spring on any one of the supports of the carbon, whose position is indicated by an index and divisions engraved on the base of the cylinder.

But what is most interesting of all in those accessories of Mr. Edison's system is the meter which determines the amount of electricity consumed by the lamps. There are two kinds, one automatic like a gas meter, the other requires weighing. They are, however, both founded on the same principle; that is to say, in the estimation of work by the weight of a copper deposit produced by the current used. We will describe these two interesting pieces of apparatus hereafter and give drawings of them; to-day we must be content with only mentioning the principle involved.

Imagine a balance having at the extremities of the beam two cylindrically rolled plates of copper forming two electrodes. Let us admit that these two systems of electrodes, which plunge into two vessels filled with a solution of sulphate of copper and furnished with fixed electrodes, are traversed in an inverse direction by the current employed, and which can cause the balance to operate under a given weight of copper deposited from the solution. It is easily seen that the movement brought about by these conditions can set in motion a current reverser, which can change the conditions of the deposits in such a way that the electrode, covered with copper, is transformed into a soluble electrode, while the one which was originally in that condition becomes the reducing electrode. From this time on an oscillating motion of the beam of the balance is established, and more or less frequently repeated, according to the rapidity of the formation of deposit; that is to say, according to the intensity of the current. As the same movement can bring about the passage of a derived current (taken from the total current) across a special electro-magnet, which commands the movement of a counter, it is easily seen (after the determination of the number of amperes corresponding to the weight of the deposit, which produces the oscillation of the balance) what is the quantity of electricity consumed.

The realization of this idea has necessitated some electro-magnetic arrangements, which we will describe in detail when we get the drawings of the apparatus.

The other system is more simple, consisting of two voltameters of sulphate of copper, whose electrodes can be easily taken out and weighed, as the work done can be calculated from the weight of copper deposited. One of these voltameters is open to the subscriber, the other is kept closed by the controller. Resistance bobbins introduced into the circuit corresponding to these resistances permit of the employment of greater or less periods of registration.

A small incandescent lamp placed beneath the apparatus, which can be thrown into circuit by a simple metallic thermometer, prevents any danger of freezing in extremely cold weather.

There is another application of Mr. Edison's light, which can be seen at his exposition in a model intended for lighting galleries in mines. In this arrangement, represented in Fig. 16, the lamp is introduced in a glass receptacle filled with water and held in suspension. Communication of the apparatus with the circuit is arranged in such a way that the points of contact are covered by water, which avoids any danger of explosion in mines infested with fire damp. To give an idea of the application of the system of Mr. Edison, we have represented in the large cut which accompanies this article, Fig. 17, the interior of a drawing-room lighted

by fixtures which we have described. The electric light as seen is projected from above downward under conditions convenient for reading or writing. This is the method which Mr. Edison seems to prefer, but it is to be noticed that, with the chandlier of which we have spoken, lighting can be obtained in any manner, and analagous to that obtained with candles or gas jets; it is a question of taste.

Mr. Edison's lamps are not alone employed in the two salons reserved for him, they are to be found in various places throughout the great nave, notably at the exhibits of Messrs. Heilman, Ducommon et Stienben (of which we gave a drawing in a previous article) and at the exhibits of Messrs. Sautter and Lemonnier. At these two places the currents are furnished by two Gramme machines, type A, and each one lights about 40 lamps. Now that Mr. Edison's great machine (a drawing of which is shown on frontispiéce) has arrived at the Exposition, it will be possible to obtain, with the incandescent system, illuminations of greater magnitude. The landing of the great staircase will be lit in this way. It is proposed to accomplish this by means of a crystal chandelier of 144 lamps, and of others furnished with 25 lamps each, to be hung from the different panals, and of girandoles standing on the 16 pilasters of the staircase. This will produce an enchanting effect and a billiant illumination. I am not quite sure that this mixture of arc and incandescent lights is a happy thought. It is evident that the latter destroy the effect of the former, and might lead one to believe that the luminous intensity of the incandescent lamp is less than it really is. Again, the difference in the color of the lights is so contrasted that many persons who reproach the electric arc for its ghastly aspect, find it too red in incandescent lamps. It is evidently an effect of contrast, for the light of incandescent lamps is whiter than that of gas jets, which, nevertheless, these same people find very agreeable. If required, incandescent lamps can give a dazzling white just as well as the others; it is only necessaryto employ a stronger electrical intensity, then they lose their peculiar qualities, that of giving a soft light which does not fatigue the eye and of an easier and more complete subdivision.

It is certainly very difficult to satisfy everybody, and many persons hardly know what they do want; above all, when the effects of contrast momentarily impair the power of judging correctly. On the other hand, there are certain faultfinding spirits who are never satisfied with anything; witness the author of that incomprehensible article that recently appeared in a certain journal, who pretended that only discordant sounds and puppet-show voices could be heard in the telephones from the opera. The author in question who could perpetuate such an enormity must have had his ear as sick as his humor. The crowd passing every evening before the telephone room at the Exposition is the best proof of the insanity of such judgments, and by this can once more be seen the value of the scientific lucubrations of certain political journals.

The same thing happens with the electric light, and quite a number of persons who, without previous examination and without being of the same opinion two days consecutively, come to us and disparage electric lighting. It is certain that new inventions have great difficulty in coming to light and in succeeding, above all when they are opposed by rival interests, but when they are really good they triumph in time over all obstacles.

We would like to give some information about Mr. Edison's new machines, but as they are not yet put up, we reserve the description for another time; we will only say that the steam engine was constructed especially for this application, that it makes no noise, and that the dynamo-electric machine forms one of its integral parts. The field magnets of this latter mentioned machine, in place of being vertical as in the model represented in Fig. 4, are horizontal, and the dimensions of the machine itself are much larger.

The steam engine which works the machine is of peculiar construction, and the speed of rotation which is communicated to the working coil is 350 turns a minute. This is not a very great speed, but the armature is very heavy, weighing, as we are told, over three tons and a

half. The magnetic fluid in which it turns is formed by three powerful electro-magnets, united so as to form one at their extremities. In the salon of Mr. Edison are a collection of photographs, among which may be seen some of the factories where the enormous amount of material required in these installations is constructed. As we have been assured, one of these turns out 2,000 lamps a day, giving occupation to 150 persons. In accompanying drawings and collections can be seen methods of glass blowing, the carbonizing of filaments intended for incandescence, the vacuum pumps and the mounting and packing of the lamps. The pumps referred to are set in motion by dynamo-electric machines.

From all this we see Mr. Edison's system to-day is completed, perfectly studied out in all parts, and that nothing more remains to be done but to introduce it on a great scale.

* * * * * *

TH. DU MONCEL.

Complainant's Exhibit "Extracts from 3d Edition of Fontaine." March 13, 1890. S. M. H., Exr.

(Translation.)

ELECTRIC LIGHTING

BY

HIPPOLYTE FONTAINE.

3d Edition, Paris, 1888, p. 396.

Chapter XIII.

INCANDESCENT LAMPS.

INDUSTRIAL LAMPS. Although they have only been introduced into general use for a very few years, incandescent lamps have quickly attracted the attention of inventors, and the number of types of different makes is increasing without ceasing. For this reason, it would be difficult, if not impossible, for us to establish to-day a complete nomenclature of the types used in the industry, and also give the names of all the manufacturers.

We have limited our inquiries to the lamps most valued, beginning of course with Mr. Edison; because we consider Mr. Edison, we cannot repeat it too often, as the true creator of incandescent lighting, and as one of the benefactors of mankind.

Concerning several systems, we have only been able to obtain very incomplete information, because of the mystery which still surrounds their manufacture; but the description of the customary methods in the large factories will suffice to give to the reader a correct idea of this new and great industry.

As far as possible, we have completed our description with a table of the lamps at present known in France * * * (pp. 404–405).

SWAN LAMPS. In England, Mr. Swan is considered to be the true inventor of the incandescent lamp. The

fact is, that long before the Edison lamp had been heard of, he attempted the construction of a practical apparatus, and he had even shown, in a public meeting, lamps sealed with a blow pipe and containing a small incandescent carbon.

But it is certain that these lamps were not yet sufficiently perfected to be utilized industrially when the Edison fibrous filament lamp appeared.

It is after the glorious success of this lamp that Mr. Swan renewed his labors and brought them to a useful end by following the road marked out by the American inventor.

* * * * * * * *

ELECTRICITY IN LIGHTING.

By Henry Morton.

IT was, we think, in reference to some electrical experiment, that Benjamin Franklin made his often quoted and most suggestive answer to the question, What is the use of it? by another question, What is the use of a baby? and nothing has better illustrated the way in which scientific discoveries, like babies, can grow into usefulness than has electricity in its various developments and applications, among which by no means the least is that to electric lighting.

Indeed this scientific infant, whose birthplace may be said to have been Sir Humphry Davy's lecture-room in the Royal Society, has not only developed into vigorous youth and useful manhood, but has also produced an extensive family of descendants, so wide-reaching and diverse in their characteristics that they must be discussed under numerous heads and various classifications, and have in many cases little in common with the founder of their family, except that electricity is the form of energy which vitalizes them, and that light is the result and evidence of their vitality.

Sir Humphry Davy in 1808 showed on a grand scale, with a galvanic battery of some two thousand pairs of plates, that when an electric circuit, established between two pieces of charcoal, was gradually interrupted by their separation, an arch or arc of dazzling light was developed between the separated pieces of carbon.

The magnificent intensity of this light attracted to it the attention of the world, and dreams as to its utility and applications were freely indulged in by many possessed of lively imaginations, but for many years there seemed little prospect that any of these dreams would be realized.

The radical and fatal difficulty was the cost of the electric energy required. Numerous improvements were made in the galvanic battery, by which its constancy of action and compactness as to bulk and weight were improved; but it always remained, and remains to-day, that the cheapest source of energy available in a galvanic battery is metallic zinc, and that metallic zinc is a costly material, with a low efficiency as compared with other substances, such as carbon or carbonaceous compounds, usually employed in the production of light. Left to the galvanic battery, therefore, the electric light, brilliant as were its capacities, would have been confined to the lecture-room of the professor and an occasional display in the theatre or opera-house, or out-of-doors on rare occasions, such as peace illuminations or national anniversaries.

In one direction much labor was spent and much improvement was made; that is, in the structure of "electric lamps" or "regulators" for the electric light.

When the electric arc is formed between the carbon terminals it causes them not only to glow and actually burn, but also to be vaporized and dissipated, so that they are consumed with considerable rapidity, and this, too, at an unequal rate, the positive terminal consuming much faster than the negative one. To provide for this, means of feeding the carbons (which for this purpose were made in the form of long cylindrical rods of the most compact and refractory kinds of carbon, such as plumbago or gas-coke) toward each other as they were consumed must be provided.

Very ingenious and efficient "lamps" or regulators were constructed at an early date. There is one now in the cabinet of the Stevens Institute of Technology, Hoboken, N. J., which was imported some time prior to 1853, and used in some of my public lectures more than twenty-five years ago. It was designed by the eminent French physicist Foucault, and constructed by the

widely known instrument-maker Duboscq Soleil, of Paris.

Lamps similar in general principle, but different in their mode of operation, were made by Deleuil, Serrin, and Duboscq in France; by Roberts, Slater & Watson, Staite, and Chapman in England; and, indeed, as far as anything that could be done with galvanic batteries was concerned, there was nothing to be desired as regards perfection and efficiency in the electric lamp or regulator of the electric light.

This child of Sir Humphry Davy had reached his full growth and intelligence, and had attained not only a brilliant but a well-regulated manhood. His usefulness to the world at large, however, as I have already pointed out, was limited by the costliness of the apparatus by which his vital energy was supplied. Having thus, after the manner of the novelist, followed one of our characters up to a position of difficulty, we will turn in another direction and look after the other who is to relieve the situation.

Again we have the birth of a great scientific discovery, and this time it is in the laboratory of Michael Faraday at the Royal Institution.

Here magneto-electric induction first saw the light, and it was first demonstrated that an electric current could be produced, without any galvanic or chemical action, by the mere motion of a conductor before a magnet.

The theory and detailed conditions of this action were fully explained by Professor Brackett in the June number of this Magazine (p. 653), and I will therefore say nothing of these, but pass at once to the practical application of this great discovery, which was soon made, and which, through a number of developments, has culminated in the dynamo-electric machine of to-day, which turns the mechanical energy of a steam-engine, of a waterfall, or of any other like motor, into an electric current, and thus enables us to secure electric energy from cheap and highly efficient coal or the like, instead of seeking it in costly and inefficient zinc.*

The first development of Faraday's discovery was made by Pixii, of Paris, who, in 1832, constructed an apparatus in which a large steel magnet was rotated so that its poles continuously and successively swept past those of an electro-magnet, or U-shaped bar of soft iron whose ends were surrounded with coils of copper wire.

This motion generated in the copper wire rapidly alternating electric currents, which were "commutated" or made to pass out of the machine in a constant direction by a simple "commutator" on the axis of the revolving magnet, which shifted the connections each time the direction of the current was changed.

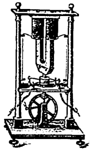


Fig. 1.—Pixii's Magneto-electric Machine—1832.

The machine of Pixii is shown in the accompanying Figure 1.

In this, near the top, are seen the copper-wire coils wound on cores of soft iron like thread on a spool. Immediately below these is the permanent magnet, of a U-shape, and so supported that it can be rapidly rotated about a vertical axis midway between its poles, so that each pole is caused to approach, pass, and recede from, in succession, each of the iron cores of the coils. Immediately below the bend of the U-magnet are the commutator segments, pressed upon by the contact brushes, and below these again is the gearing by which the magnet is made to rotate.

Machines operating on the same principle, but varying in construction (as, for example, by rotating the electro-magnet or coils of copper wire while the steel permanent magnet remained stationary) were brought out by Saxton, of Philadelphia, in 1833; by Clark, of London, in 1834; and by Page, of Washington, in 1835.

None of these machines, however, were of sufficient size to be available for the production of a practical electric light, although they all exhibited a capacity for this effect on a minute scale.

* The total efficiency of a pound of zinc is only one-sixth that of a pound of carbon.

The first magneto-electric machine of a magnitude sufficient to operate a practical electric lamp was that produced by the united labors of M. Nollet, Professor of Physics at the Military School of Brussels, and his assistant constructor, Joseph Van Malderen, under the auspices of a corporation composed of

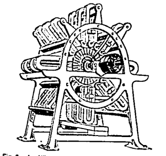


Fig. 2.—An Alliance Dynamo used in the South Foreland Lighthouse, 1858.

French and English capitalists and known as the "Alliance Company."

Strange to say, this machine was built with the absurd object of using it to decompose water and employ the resulting gases in the production of light.

This machine, with some modifications by Mr. Holmes, of England, was, under the superintendence of Faraday himself, introduced into two of the English light-houses, *i.e.*, at South Foreland and at Dungeness. Its preliminary trial was made in 1857. The electric light was first thrown over the sea from the South Foreland on the evening of December 8, 1858, and from Dungeness on the 6th of June, 1862.

Figure 2 shows in outline one of the Alliance machines, as modified by Mr. Holmes, which was long since put in operation at the South Foreland Lighthouse.

The outer framework supports twenty-four compound steel permanent magnets, and a drum inside carries thirty-two armatures or spools of copper wire wound on iron cores. As these pass from pole to pole between the magnets, currents are developed which are carried off by commutators on the farther end of the shaft, not shown.

The electric light was not introduced into the French light-houses until December 26, 1863, when it was installed at La Hève, near Havre. It was also used for lighting works of construction, such as the Cherbourg Docks, and on some vessels, for example, on the Lafayette and the Jerome Napoleon.

Although Faraday lived to see the little spark, which he had developed from a magnet and coil of wire in his laboratory, grow into these magnificent illuminators of sea and land, it was not until after many years and numerous new developments that the electric light approached the commercial utility which it to-day possesses.

These Alliance machines, on account of their great size and multitude of parts, were very expensive. Thus the two machines placed in the Dungeness Lighthouse, with their engines, appliances, and lamps or "regulators," cost £4,760, or nearly $24,000. The two located at Souter Point in like manner cost £7,000, or about $35,000, and the machines and accessories for the two lights at South Foreland cost £8,500, or about $42,500. The same characteristics caused them to be liable to accident and injury and costly in repairs. The world therefore waited for some further development before it could enjoy generally the advantages of electricity as a means of illumination.

The first of these came when Dr. Werner Siemens, of Berlin, constructed a machine in which the revolving coil or armature was made of the form shown in Figure 3, and was entirely enclosed between the ends of the permanent magnets. To construct this armature a long, solid cylinder of soft iron is taken, and two deep grooves are cut on opposite sides through its entire length, so that its cross-section is such as appears at F in

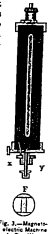


Fig. 3.—Magneto-electric Machine of Dr. Werner Siemens.

the accompanying figure. Insulated copper wire is then wound lengthwise in these grooves, its ends being united to the sections x, y, of the commutator. Journals on which this armature rotates are provided at either end, and at one end also a pulley by which it may be driven by a belt.

This armature secured a great concentration of action, by bringing the revolving armature into a highly concentrated field of magnetic force and allowing it to have a very rapid angular velocity of rotation. But the chief value of this improvement consisted in its serving as a step toward another, which was most remarkable in its results and excited the liveliest interest all over the world when it was announced. This next step was taken by Wilde, of Manchester.

He took a small magneto-electric machine, such as had been constructed by Siemens, and carried the current from its commutator to the coils of very large electro-magnets, which constituted the field-magnets of a similar machine, which, however, differed from the other, or Siemens machine, both in size and in having its field constructed of electro-magnets in place of permanent magnets.

Figure 4 shows such a combination, in which the first or small magneto-electric machine is mounted on the top of the other, and sends the current from its commutator through the coils of the electro-magnet below, between whose expanded poles another Siemens armature is made to revolve.

Under these circumstances the current developed in the armature of the upper machine, by its permanent steel magnets, will develop a more than tenfold greater magnetic force in the poles of the electro-magnet of the lower machine; and the second armature, rotating in this powerful magnetic field between the poles of this large electro-magnet, will develop a more than tenfold greater current than that of the smaller machine.

This method of multiplying or creating magnetic force was a wonderful discovery, and, combined with the use of electro-magnets in place of permanent magnets for the production of the magnetic field, gave an important increase in power and efficiency to the machine; for, as compared with permanent magnets, the power of electro-magnets is vastly greater.

This advance, made by Wilde on April 13, 1866, was quickly followed by another, made almost simultaneously in Europe by Varley, Siemens, and Wheatstone, and nearly a year earlier in this country by Mr. M. G. Farmer, whose work in another department of electric lighting we shall have occasion to mention farther on.

This development may be indicated by the term "self-exciting," and consisted in the discovery that if the commutator is so connected with the coils constituting the field magnets that all, or a part of the current developed in the armature will flow through these

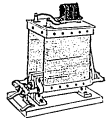


Fig. 4.—The Wilde Machine.

Small machine or feeder, with permanent magnets on top; large machine, with electro-magnets yielding available current below.

coils, then all permanent magnets may be dispensed with, and the machine will excite itself or charge its own field magnets without the aid of any charging or feeding machine such as the little one shown in Figure 4.

There is in all iron, unless special means have been taken to remove it, a little magnetic force. This small magnetic force, called "residual magnetism," in the iron cores of the field magnets will produce a little current in the armature when it is revolved. This current flowing through the coils of the field magnets will increase their magnetic force, and thus cause them to develop more current in the armature, which in turn, flowing through the coils of the field magnets, will further increase their magnetic force, and so on until a maximum, determined by the structural conditions of the machine and the amount of driving force applied to the pulley of the armature, is reached.

In practice such machines are each complete within themselves. When started they develop for a few moments only very feeble currents, but within a few seconds they "wake up" by degrees, and reach their maximum in less time than it takes to read this paragraph.

One other radical improvement in dynamo-electric machines remains to be recorded, namely, that due to the French inventor Gramme.

The essence of this lay in the structure of the armature. While previous to Gramme all armatures had been constructed either like spools of cotton or like balls of yarn wound on blocks, he made his armature by starting with an iron ring (itself consisting of a coil of soft iron wire) and winding the copper wire on this by passing the end of the wire again and again through the ring. A Gramme armature ring, cut and bent out partly, and with some of its copper coils removed, is shown in Figure 5.

The cut ends of the iron wires constituting the ring-core are shown at A, and B shows a portion of the copper-wire coils wound around this ring-core. The copper wire is continuous through-

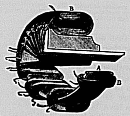


Fig. 5.—Section of a Gramme Armature Ring, showing its construction.

out as regards its electric connection, but at frequent intervals a loop of this wire is carried out and attached to a segment of the commutator.

This armature being rotated in a magnetic field (*i.e.*, between the poles of powerful field magnets) tends to deliver a substantially continuous current to "brushes" touching the commutator segments at points midway between the poles of the field magnets.

Théophile Gramme.

It will be remembered that the iron ring constituting the core of the Gramme armature was made of iron wires, and not of a solid piece or ring of iron. The object of this was to prevent the formation of electric currents in this ring-core itself, commonly called Foucault currents, which would be a cause of inconvenience by heating the armature and of loss by wasting energy in the useless production of this heat.

The Siemens armature had no such provision, and accordingly very serious difficulties were experienced in the running of machines using such armatures, by reason of the intense heat there produced. Arrangements were in fact made in many machines to relieve this symptom by running cold water through the armature, made hollow for that end; but this did not cure the disease, or prevent the loss of efficiency caused by the conversion of the driving energy into useless heat in place of useful current.

The desirable end was, however, soon secured by "laminating the armature core," that is, making it up out of a great number of thin sheets of iron insulated from each other and held together by one or more bolts. The building up of such an armature core is illustrated in Figure 6.

The merit of this invention appears

to have been assigned by the U. S. Patent Office to Mr. Edward Weston, of Newark, N. J., who on September 22, 1882, filed an application in the U. S. Patent Office describing such a laminated armature core, for which two patents were granted, April 16, 1889, being Nos. 401,668 and 401,669.

We have given above all of the radical steps or improvements by which the dynamo-electric machine of to-day has been developed from the earlier constructions of Pixii, Clark, Saxton, and Page, or, in fact, from the experiment and discovery of Faraday.

There were, however, during the same time, a multitude of minor modifications of structure and arrangement introduced by various inventors, some useful and some useless, and when the world had been startled and interested by some of the wonderful developments, such as those of Wilde and of Gramme, it was found that in some forgotten patent or other publication some description might be read more or less completely anticipating these important discoveries.

We have not attempted to follow out the subject in this relation, which, however important in its legal consequences, as affecting the rights of patentees, is not a part of the general history of the actual development of the electric light which we have attempted to write.

An endless variety has also been given to the forms and arrangement of the more recent dynamo-electric machines manufactured by the various companies, but these it would likewise be impossible for us to discuss within the limits of a magazine article.

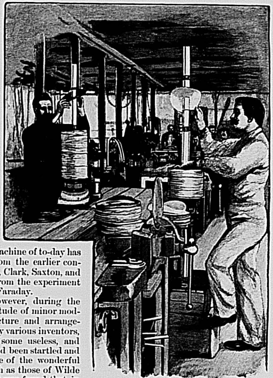


Fig. 6.—Workmen Building up the Armature Core of a Modern Dynamo.

I will therefore select a typical case, and give some account of its mode of construction.

The most difficult and important part of the structure is the armature, and in building this the first thing is the laminated iron core. For this purpose an immense number of thin disks of sheet iron are cut out, each having a central hole to admit the shaft, and several other holes for the bolts which are to hold the series of disks together, so as to make of them a solid drum. These disks are then piled one upon another around the iron shaft which is to form the axle of the armature, as shown in

Figure 6, and thick iron end-plates are applied at either end and bolted together by iron bolts going through from end to end. The drum or cylinder thus formed is then mounted in a lathe and turned to a smooth surface, except for such projections as may be left for guides in winding-on the copper wires.

Fig. 7.—Winding an Armature.

This is the next operation to be performed, and is shown in Figure 7, which represents the winding of a large armature intended to produce a very heavy current, and therefore wound with thick wire.

The workman in front is drawing the insulated copper wire down from a drum overhead and passing it lengthwise around the armature-core, which is supported by its axis in a lathe, while another workman assists him in pressing the wire accurately into place and keeping it close to the core. This wire is not wound on continuously, but in a number of short sections whose ends are seen sticking out somewhat irregularly. These ends are to be attached to the successive sections of the commutator which is presently to be passed over the end of the shaft, appearing at the left.

Figure 8 shows just such an armature as that in Figure 7, but finished and turned the other way, so that though the position of the observer is reversed he still sees the commutator end of the armature turned toward him. The numerous radiating lines at the nearer end of the drum are parts of the commutator-sections, which are attached at their outer ends to the successive coils of wire on the armature. At their nearer ends these radial bars bend at right angles, so as to pass along the surface of the shaft, being insulated from it and from each other by mica or other appropriate substance.

The workman in this figure is engaged in putting on the last turns of binding wire, which is wound in several bands, as shown, around the armature, not for any electric action but to hold the coils, which run lengthwise round the drum, firmly in place and prevent them from being spread outward by centrifugal force when the armature is in use. These binding wires are made of German silver, a bad conductor for a metal, and are thoroughly insulated from the copper wires of the armature.

The armature, having been thus constructed, is now ready to be mounted in the framework of field magnets, which has been constructed in another department of the factory.

This is shown in Figure 9, and consists of a massive framework of cast-iron, portions of which are surrounded with coils of insulated copper wire so as to make the central parts of the upper and lower horizontal masses respectively north and south poles.

It is in the cylindrical hollow between these that the armature rotates, one end of its shaft being supported in the journal-box seen at the right, while the other end is supported in a journal-box out of view on the other side of the machine.

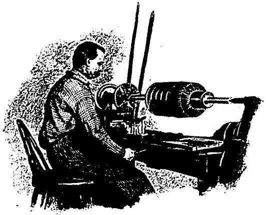


Fig. 8.—Finishing an Armature.

The adjustable supports to hold the brushes, or elastic strips of copper which press against the commutator and take off from it the current generated in the armature, are then attached to the sides of the bracket which carries the nearer end of the shaft, and the machine is substantially complete, the driving pulley being of course attached, when needed, on the farther end of the shaft.

Figure 10 shows this same machine completed in all respects, with the armature inserted, the brushes in place, and the driving pulley on the farther end of the shaft.

The dynamo-electric machines of Weston, of Edison, of Brush, of Thomson-Houston, of Westinghouse, and a dozen others are all constructed (with considerable variations in form and detail), in the manner above described, and by their aid mechanical energy can be transformed into electric energy with an economy entirely unparalleled by any transformation heretofore known to the arts. Thus in the steam-engine we may, under very favorable conditions, transform ten per cent. of the energy of the fuel into mechanical energy, but under the average working conditions we only secure about five per cent., the other ninety-five per cent. being lost.

In the dynamo-electric machine, on the other hand, it is very common to secure a transformation of eighty per cent.

of the mechanical energy, applied to the driving pulley, into electric current, and in many cases as much as ninety per cent. is so transformed and only ten per cent. is lost.

Cheap electricity having been thus secured by the development of the dynamo-electric machine, the electric regulator or lamp acquired a new importance, and new demands were made upon the inventive genius of the world on its account.

As long as expensive batteries were the only sources of electric energy, it was considered quite enough to operate one lamp at a time; but when the great capacities of the dynamo-machine were to be realized, it became clear that for economical working many lamps must be operated from one machine, and, if possible, in a single circuit or one after the other. For this the old regulators were not adapted. They all operate in the following general method:

The current which supplies the lamp passes through an electro-magnet which controls a clock-work or other mechanism which allows or causes the carbon poles to approach each other whenever the strength of the current is reduced.

As soon, therefore, as the burning away of the carbon poles causes an increase in the resistance of the arc or space between them by increasing its length, the resulting diminution of the current causes the electro-magnet to release or actuate the feeding device, until the poles are brought near enough to diminish the resistance of the arc to its normal amount.

With a single lamp in circuit this is all that is required, but it will be manifest that anything which causes a diminution in the current will cause the carbons to be brought nearer. Now suppose that two such lamps are arranged in series so that the current flows first through one and then through the other, and that, as must always be the case, one mechanism is a little (no matter how little) more sensitive than the other; then, when either pair of carbons burn away enough to diminish the total current to the point at which the more sensitive mechanism will act, that mechanism will so act, and will bring its carbons toward each other, until the resistance is diminished far enough to restore the normal current, and this will happen without the less sensitive mechanism being brought into action at all. This operation will then go on; the carbons of the less sensitive lamp burning away farther and farther, and their increase of resistance being made up by the approach of the carbons of the more sensitive lamp until the latter is extinguished by the actual contact of its carbon poles and the less sensitive lamp has secured an excessively long arc which is absorbing the entire energy of the circuit.

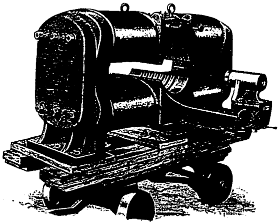


Fig. 9.—Field Magnets and Frame, without armature.

The same thing would happen with any number of such lamps in series. The most sensitive of the lamps would do the adjustment for all the rest, until its poles were brought into contact, and then the next in order of sensitiveness would take its turn, and thus one after the other would be thrown out of use, and the entire energy of the circuit would be concentrated in an abnormally long and probably destructive arc in the least sensitive lamp. Numerous plans were suggested to meet this difficulty, but the only ones which have reached any general practical success are those of Jablochkoff and of Brush.

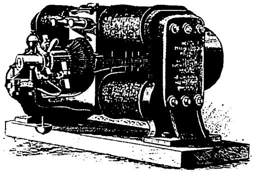


Fig. 10.—A Complete Dynamo—armature in place.

Jablochkoff substituted for the lamps whose carbons were moved by mechanisms of some sort his electric candles with immovable carbons. In these the two carbon rods were placed side by side, vertically, very near to each other, the space between being filled with plaster-of-Paris.

An arc having been established between the upper ends of the carbons by a thin strip of carbon which was quickly burned away, the same continued as the carbons consumed, because the plaster-of-Paris between them melted and volatilized as fast as the carbons were consumed. (Figure 11.)

These Jablochkoff candles were used to a considerable extent in Europe in the early days of electric lighting, but never made much progress in the United States, being very inferior in efficiency and economy to lamps arranged on the Brush or other similar systems.

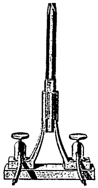


Fig. 11.—The Jablochkoff Candle.

The arrangement first introduced in this country as I believe by the Brush Electric Co., and now universally used in one or another modification, may be described in general terms as follows: There are two electro-magnets or coils controlling the feeding mechanism which tend to oppose each other in the motions they produce. Through one of these the current passes which also traverses the arc of the lamp, but the other magnet or coil is traversed by a current branching from the former where it enters the lamp, and rejoining it where it passes out, but not going through the arc. This last-named coil has a higher resistance than the other, and normally transmits but a small fraction of the current as compared with that passing through the arc and the other coil.

If, now, by the burning away of the carbons, the resistance of that circuit is increased, two things happen at once: the current through the other coil, which is not in circuit with the arc, is increased at the same time that the current through the arc and *its* coil is diminished, so that the total current through the lamp remains substantially unchanged, and therefore nothing which happens in one lamp has any effect on the circuit at large or on any other lamp. Also the opposite magnetic effects in the two coils cause a rapid readjustment of the carbon electrodes and a consequent restoration of the arc to its normal length.

After this arrangement had been developed by the Brush Electric Co. some old patents were discovered in which the same principle was to a greater or less extent set forth, but as in the case of the Pacinotti article and the Gramme machine, these do not seem to have had anything to do with the practical development of the art of electric lighting prior to Mr. Brush's invention.

As with the dynamo-electric machines, so with the regulators or electric lamps for arc lights, their varieties of construction are endless, but they all come under the general description of holders for the carbon rods, whose motions are controlled by feeding mechanisms which are in turn controlled by electromagnets through which the operating current flows.

Such structures have reached a marvellous perfection as regards their regularity and certainty of action. Among the thousands of lamps which light our streets and stores night after night, a failure in operation is almost unknown to the ordinary observer. Irregularities, such as are incident to the unequal burning away of the carbon points, of course frequently occur; but the extinction of a light through any failure of the mechanism of the lamp is of the rarest occurrence even where the lights are placed in the most exposed and inaccessible positions. A striking example of this was furnished in the lights erected and maintained for some time by our Light-house Department at Hallett's Point for the purpose of lighting up the difficult channel of the East River, known as Hell Gate, illustrated in Figure 13. These lights, nine in number, arranged so as to form about three-fifths of a circle, were supported at a height of two hundred and fifty feet by a light iron tower. Each light gave, by actual measurement, an amount of light equal to three thousand standard candles, or about four times the light given by the ordinary electric lights employed in streets and buildings.

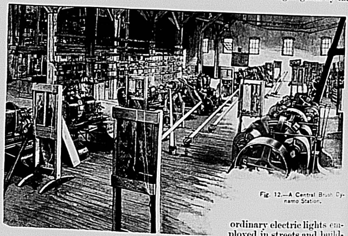


Fig. 12.—A Central Brush Dynamo Station.

These lights were put in operation on October 20, 1884, and produced a magnificent effect, lighting up the whole surrounding town of Astoria and the adjacent channel. After several years of use it was, however, decided that they did not afford the expected aid to navigation, and they were removed in 1888.

During all these years, however, there was no failure caused by the mechanism of the lamps.

The number of arc lamps which are nightly operated by the different electric lighting companies in the city of New York is probably over five thousand, and throughout the United States it probably reaches seventy-five thousand. Assuming that these lights are worth to their users the moderate rental of fifty cents a night, this represents an output of light having a value of $11,250,000 each year of three hundred days; all earned by this one branch of the family directly descending from the baby spark born from a magnet in the laboratory of Michael Faraday.

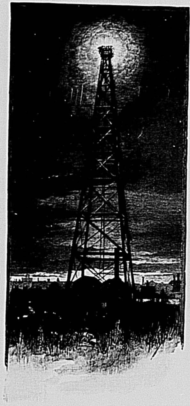


Fig. 13.—Hell Gate Light, New York, before it was abandoned.

Admirable as is the system of electric-arc lighting, for use in streets and open spaces, and in workshops or large halls, it is entirely unfit to take the place of the numerous lights of moderate intensity, employed for general domestic illumination.

For this purpose it was at a very early period perceived that the incandescence or heating to luminosity of a continuous conductor by an electric current was the most promising method. It was also at a very early period perceived that the conductor to be used for this purpose must be one which would admit of being raised to a very high temperature without being melted or otherwise destroyed. The first material which was thought of in this connection was platinum, or one of its allied metals, such as iridium, which have the highest melting-points among such bodies, and are besides entirely unacted upon by the air at all temperatures. In 1848 W. E. Staite took out a patent for making electric lamps of iridium, or iridium alloys, shaped into an arch or horseshoe form.

One of the most serious difficulties, however, even with these materials, was that, to secure from them an efficient light, it was necessary to bring them so near to their fusing-points that a very minute increase in the current would carry the temperature beyond this and destroy the lamp by fusing the conductor. An escape from the difficulty was offered by the use of hard carbon, such as that employed for the electrodes of arc lamps, but here the compensating drawback was encountered, that this substance, when highly heated, was attacked by the oxygen of the air, or, in other words, burned. To meet this, plans were devised for the replacement of the consumed carbon conductor and for its protection from the air by enclosing it in a non-active gas or in a vacuum.

Under the Electric Light.

Thus in 1845 a patent was taken out in England by Augustus King, acting as agent for an American inventor named J. W. Starr, for an incandescent lamp, the important parts of which are represented in Figure 14.

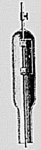


Fig. 14.—The Starr-King Incandescent Platinum Lamp, 1845.

Here a platinum wire is sealed through the top of a small glass chamber constituting the upper end of a barometer tube. This platinum wire carries at its lower end a clamp, which grasps a thin plate or rod of carbon, and also a non-conducting vertical rod or support, which helps to sustain another clamp, which grasps the lower end of the carbon strip and connects it by a wire with the mercury in the barometer tube below.

By passing a current through the platinum wire, and thence through the upper clamp, carbon strip, lower clamp, wire, and mercury, the carbon strip could be made incandescent, and was to a certain extent protected by the surrounding vacuum.

Though this lamp produced a brilliant light it proved in various respects unsatisfactory, and was abandoned after numerous trials.

Other inventors, as, for example, Konn, of St. Petersburg, continued to work with rods or pencils of hard carbon and achieved a limited success, but the irregularity and brittleness of the material seem to have been an insuperable objection and drawback, and the problem of commercial electric lighting by incandescent conductors yet remained without a solution.

This was the state of affairs even up to the fall of 1878, when, as is claimed, Mr. William E. Sawyer, in combination with Mr. Albon Man, after many preliminary experiments, produced their first successful incandescent lamp with an arch-shaped conductor made of carbonized paper. In their application for a patent, filed January 8, 1880, these inventors use the following remarkable language in their fourth claim: "An incandescing arc of carbonized fibrous or textile material." This indicates that they realized the importance of what seem to be the common features of the present electric incandescent lamps, namely, the arc or arch or bow or loop form, and the carbonized fibrous or textile material. They also specially refer to carbon incandescent conductors made from paper.

After a long and hotly contested interference the United States Patent Office has granted them a patent in which these points are broadly stated, and the merits of this patent are now actively litigated.

The lamp brought out by Messrs. Sawyer and Man, soon after their application for a patent, and described and shown in that application, was a rather large and complicated structure; and had no improvement and simplification of this structure been made, the present immense development in electric lighting would no doubt have been unattained.

It is to Mr. T. A. Edison, without doubt, that we owe many of the simplifications and modifications which, by cheapening the lamp and diminishing its weight, have extended its range of use and its usefulness to a remarkable degree.

On his return in the fall of 1878 from the Far West, where he had gone in company with Dr. and Mrs. Henry Draper, Dr. George F. Barker, and the present writer, to observe the total solar eclipse of that year, Mr. Edison visited the shops and laboratory of Mr. William Wallace, at Ansonia, Ct., where many experiments with electric-arc lights and dynamo-machines were in progress, and while studying these, was impressed with the desirability of producing an incandescent electric lamp.

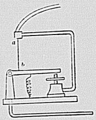


Fig. 15.—Edison's First Incandescent Platinum Lamp.

Like so many before him, he first turned to platinum and platinum alloys, and devised a form of lamp admirable for its simplicity, but, unfortunately, open to a fatal objection. This first lamp of Edison's is shown in Figure 15, in which *a b* is the incandescent platinum wire.

The announcement of a new system of electric lighting, made by Mr. Edison and his friends on the foundation of this device, attracted universal attention, and even caused a serious fall in the value of "gas stocks" in this country and abroad. It is, indeed, amusing now to look back upon the extravagant assertions and predictions made at that time, and widely circulated, when we realize how more than frail was their foundation. In fact, Mr. Edison very soon found out that this simple device was entirely insufficient for the purpose proposed, because the heated platinum wire gradually stretched by its own weight, and thus was constantly getting out of adjustment, and finally would become attenuated and break.

It also happened that, though the secret of this great invention was carefully guarded, some inkling of it escaped, and this enabled those who were familiar with such subjects to perceive the close similarity between this Edison lamp and

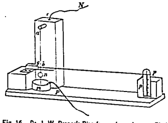


Fig. 16.—Dr. J. W. Draper's Plan for an Incandescent Platinum Lamp, 1847.

a b is the incandescent platinum wire or strip, supported above by the brass pin at *a*, which runs into a cavity, *e*, filled with mercury and is thus connected with the battery wire *N*. The other end of the platinum wire or strip is attached to a delicate lever, *g p*, turning about the fulcrum *g*; a little weight, *n*, tends to keep the wire stretched, and communication is made through it by a copper wire with the cup *m* filled with mercury, into which dips the other battery wire *P*.

a similar device constructed and used by Dr. J. W. Draper prior to 1847, and described and figured in articles published by him during that year in *The American Journal of Science and Arts*,

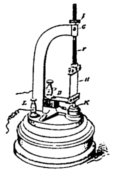


Fig. 17.—Maxim's Incandescent Platinum Lamp.

H is a strip of platinum, adjustably supported by means of the screw *F* and nut *I*, from the standard *G L*, from which it also receives an electric current which normally passes out through *D*; but when, by excessive heat, the platinum strip is elongated unduly, a short circuit is closed at *K*, which diverts the current from the standard and platinum strip, and so prevents the fusion of the latter.

The London, Edinburgh, and Dublin Philosophical Magazine, and *Harper's New Monthly Magazine*. This apparatus of Dr. Draper is shown in outline in Figure 16. It was used by Dr. Draper as a source of light or lamp with which he determined the relations between temperature and luminosity. At the conclusion of his article Dr. Draper says: "An ingenious artist would have very little difficulty, by taking advantage of the movements of the lever, in making a self-acting apparatus in which the platinum should be maintained at a uniform temperature notwithstanding any change taking place in the voltaic current."

It also appeared that precisely the same idea had occurred to another inventor, Mr. Hiram S. Maxim, who has recently developed such a marvellous improvement in magazine or repeating guns, and who, on December 22, 1879, filed an application for a patent which, after an interference litigation with Edison, was finally issued to Maxim on September 20, 1881, for the form of electric lamp shown in Figure 17.

It has also been shown that in 1858 Mr. M. G. Farmer, one of the veteran electricians of America, to whose work in connection with the dynamo-electric machine allusion has been made before, lit a room in his house at Salem, Mass., for several months, with platinum lamps of similar structure controlled by automatic regulators.

During 1878 and 1879, however, Mr. Edison was most diligently at work, and, perceiving the imperfections of his first ideas, sought in every way to overcome them. It thus came to pass that by December 21, 1879, at which date he made his first revelation to the public, in the pages of the *New York Herald*, he had perfected a platinum lamp which is shown in outline in Figure 18, as well as some other forms substantially like it.

But these platinum conductor lamps were not the only outcome of Mr. Edison's work between the fall of 1878 and December, 1879. As this *Herald* article also related, Mr. Edison, like many before him, having experienced the insuperable difficulties present in metallic con-

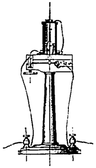


Fig. 18.—Edison's Platinum Lamp on Column Support, 1879.

The incandescent wire of a platinum alloy is supported by a metallic rod about which it is wound and whose expansion serves to operate a shunting contact below, by which an inconveniently high temperature is avoided.

ductors, had turned his attention to carbon in various forms; and, like Sawyer and Man, had found fibrous textile materials, when carbonized, to be most convenient, and paper especially to be, in the first instance, the most available substance. Like Sawyer and Man he had also found the arch or horseshoe form to be the most desirable.

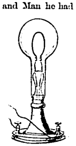


Fig. 19.—Edison's Paper Carbon Lamp.

Though working with the same materials and form, Edison produced a structure very different in appearance from that of Sawyer and Man, as will be seen by reference to Figure 19, which represents one of Edison's paper carbon lamps, which was the first one whose electric properties were accurately measured, these measurements having been made at the Stevens Institute of Technology, early in 1880, by the present writer, acting in his capacity as Chairman of the Committee on Scientific Tests of the United States Light-house Board, that body desiring information as to this new light, and deputing the work of investigation to this committee.

In this lamp the carbon conductor is supported on platinum wires and held in minute platinum clamps at the ends of these wires, which are sealed through the walls of the pear-shaped enclosing tube in the manner which had been familiar for twenty years in the construction of the beautiful electric toys known as "Geissler tubes."

The interior of this glass vessel had likewise been exhausted and hermetically sealed in the manner usual with many Geissler tubes and with the radiometers of Dr. William Crookes.

Indeed, as was subsequently made apparent, the wonderful results obtained by Dr. Crookes, in the production of very perfect vacua, were of essential importance to the development of the incandescent electric lamp. Several of the instruments produced by Dr. Crookes in the course of his researches were in fact incandescent electric lamps, consisting of coils of platinum wire enclosed in glass vessels exhausted to a very high degree, the coils being heated to brilliant luminosity by electric currents. One of these is shown in his paper in the "Philosophical Transactions for 1876," vol. xlvi., Part II., page 351.

Further experience proved to Edison and others that *paper* carbons were not the best for the conductors of electric lamps, and many other substances have been, or are now, employed for this purpose. Among these may be mentioned silk, hair, parchmentized cotton thread, tamodine or reduced celluloid, and last, but not least, bamboo, which is used to a very large extent.

The making of these electric lamps is carried on in a number of large factories, such as that of the Edison Co. at Harrison, near Newark; those of the Westinghouse Electric Co. at Newark and at Pittsburg; that of the Consolidated Electric Co. at West Twenty-third Street, New York; that of the Thomson-Houston Co. at Lynn, Mass.; that of the Brush Co. at Cleveland, O., and a number of smaller establishments elsewhere. The daily output of all these factories taken together is about fifteen thousand lamps, or four and a half million a year.

The methods of manufacture are substantially alike in all, and I will therefore describe one only as an example.

Sheets of tamodine (or celluloid from which the nitric constituent has been removed) are cut by a machine into delicate strips or filaments, which are collected in small bundles and bent so as to lie in U-shaped grooves in iron plates. These, packed with carbon powder, are enclosed in large black-lead crucibles, carefully closed, and heated in a Siemens furnace to an intense white heat. After cooling, the crucibles are opened, and the now carbonized filaments, looking like delicate wires or threads of steel, are removed. They have now the U-shape into which they were bent before carbonizing, but are so elastic that they can be stretched out straight without breaking. Their ends are next thickened by a remarkable process devised by Messrs. Sawyer and Man, and which is conducted as follows: Each U-shaped fibre is grasped by two clamps, one holding it by the extremities or ends, and the other at a little distance above. The loop and clamps are then plunged in a vessel of high-boiling petroleum-oil, like the well-known "astral oil," and a powerful electric current is passed from the clamps through the short portions of the filament, near its ends, which are grasped between them.

By this means these portions are intensely heated and decompose the hydrocarbon liquid in contact with them, so as to plate themselves with compact carbon like that deposited from the gas in the necks of gas-retorts. A few seconds' action suffices to make this deposit of carbon thick enough to answer the desired purpose.

We will next turn to the glass-blowing department, where hundreds of girls are employed in all the delicate and skilful manipulations involved in the glasswork of these lamps.

The first step is to take two minute pieces of platinum wire, one end of each having been shaped into a little socket capable of holding the enlarged end of the carbon filament; and, after mounting them in a small lathe-chuck, to wind melted glass from a glass rod, heated in a glass-blower's lamp, around these platinum wires until they are for some distance embedded in glass and formed into a structure such as is seen at the lower part of the ordinary incandescent lamps. Into these glass and platinum supports are then inserted the enlarged ends of the carbon filaments.

In the meantime small glass flasks, made by the thousand at the glass-works, are passed through a variety of manipulations by which a small glass tube is attached to what would be the bottom of each flask, and its neck is shaped so as to receive the glass socket carrying the platinum wires and carbon filament. At the proper time this socket is dropped into the prepared flask, and by manipulation with the glass-blower's lamp and a sleight of hand which is simply marvellous, the glass socket, with its carbon filament and connecting wires, is sealed, by fusion of the glass itself, into the neck of the flask.

This operation is shown in progress in Figure 20, where the girl in the foreground holds in her left hand the glass flask by the glass tube which has been attached to it, and in her right hand the

Fig. 20.—Sealing the Glass Socket and Carbon Filament into the Flask of an Incandescent Lamp.

shears with which she at times holds and shapes the glass socket and neck of the flask. The blow-pipe flames, constituting what is called the "glass-blower's lamp" or "fire," are seen as pointed tongues of light between the hands of the operator, who is supposed at the instant represented to have just raised an electric lamp, finished (so far as her work is concerned) from the flame.

The next thing to be done with the lamps is to exhaust them. For this purpose they are attached by the small glass tubes before mentioned to radiating glass connectors, and these are in turn attached to the pumps, while at the same time electric connections are made so that currents can be sent through the filaments of the lamps while they are being exhausted by the pumps. These pumps are themselves entirely composed of glass, and operated by the flow of mercury back and forth within them, and their operation is so nearly automatic that a few attendants can keep a large number of them in steady operation.

When a good vacuum has been reached, the current is passed through the lamps and they are then kept at a brilliant incandescence for some hours, in order to drive out any gas which might be occluded in the carbon filaments or adhere to the interior surface of the glass. This process of exhaustion and a series of pumps and lamps in operation during the process are shown in Figure 21.

After the complete exhaustion of the lamps it then only remains to "seal them off," that is, to melt the small glass tube attached to each so that its sides close together, and it becomes a little knob of glass, and to attach the brass caps by which they are to be subsequently connected to their sockets.

The uses of these lamps are so countless and so familiar to everyone that we have only selected one unusual one for illustration, namely, the lighting of the Hoosac Tunnel, which has recently been carried out by this means in the face of great difficulties encountered in securing adequate insulation, in such a situation, for the wires carrying the current to the lamps. The lamps are attached to the rock or to the stone lining of the tunnel in the manner shown in Figure 23, (p. 196) and produce when in operation the effect shown in Figure 22.

As we have seen so often already, the solution of one problem always opens up another, and thus it is not surprising that the cheapening of electricity and increased efficiency of incandescent lamps brought to the front the problem of an economical method for carrying the electric current from the generator to the lamps.

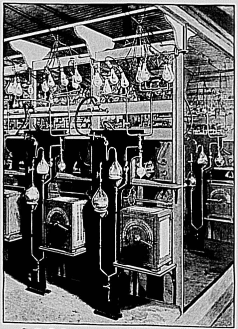
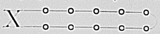


Fig. 21.—The Process of Exhausting the Air from Incandescent Lamps.

There were two well-known systems which had been often used in other applications of electricity, and, indeed, even described and patented for use in electric lighting, namely, what are commonly known as the "series" and the "parallel" systems.

The "series" system is that always and necessarily employed whenever more than one arc light is used on the same circuit, and may be likened to the arrangement of disks on the chain of a chain-pump, or illustrated by the accompanying diagram, in which X represents a dynamo-machine and o, o, o, o, etc., represent a series of lights connected by the circuit wires —, —, so as to form a single chain from the machine through all the lights in succession back to the machine again.



This was the usual arrangement of the telegraph instruments at the various stations on a line.

The "parallel" or "multiple arc" system was one which might be indicated by a ladder or by the accompanying diagram, where, as before, X represents the dynamo, from whose poles proceed two main conductors between which the lamps o, o, o, etc., are placed in cross connections.

This was a method commonly employed in central telegraph offices for operating the sounders by means of the large "local" battery. It is also described in the United States Patent to H. Woodward for improvement in electric lights, granted August 29, 1876, as well as in many other places.

The first method has certain drawbacks which are specially important in the case of incandescent lamps, where, for economy, a large number should generally be operated on a single circuit:

Fig. 22.—The Hoosac Tunnel Lit by Glow Lamps, after the plan of the Marr Construction Company.

1. The extinction of one lamp means the extinction of all, unless some more or less complicated mechanism is provided to restore the connection around the lamp which has failed or has been turned out.

2. The electro-motive force, or electric pressure, needing to be multiplied in direct proportion to the number of lamps in the circuit, soon becomes inconveniently high.

Both of these difficulties being avoided in the "parallel" system, this last has been generally adopted by all the companies using incandescent electric lights for most of their work. This is, however, by no means universal, for the Edison Co., in what they call their "Municipal system" (used mostly for street lamps in small towns and villages), run incandescent lamps in series. Other companies often run their lamps in a combination of the two systems, and the Heissler Co. run their lamps in "series" exclusively.

In avoiding the difficulties of the "series" system mentioned above, the parallel or multiple-arc system encountered others, the chief of which was the great size and cost of the conducting wires, if the distance between the dynamo and the lamps was considerable. Suppose that a group of lamps was placed one thousand feet from a dynamo, and the wires used were of such a size that their resistance to the flow of the current caused them to waste ten per cent. of the energy developed. Now let us suppose that this group of lamps is moved away one thousand feet farther. This would, of course, mean doubling the length of the wires, which alone would double their cost; but it would also mean doubling their resistance, if they were not made larger than before, and so wasting twenty per cent. of the electric energy generated by the dynamo.

To avoid this loss we must make the wires twice as heavy per running foot, and if we do so we can then reduce the loss at two thousand feet to ten per cent. as before, but clearly we have four times the weight of copper to pay for in our conductors. If the lamps are removed to a total distance of three thousand feet we shall have three times the length of wire, and to keep down its resistance to that producing a loss of only ten per cent., we must make the wire three times

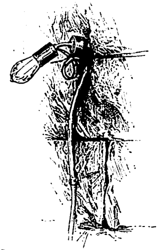


Fig. 23.—Method of Attaching Glow Lamps to the Walls of the Hoosac Tunnel.

as heavy per foot, or, in all, we shall require nine times as many pounds of wire to operate the lights at a threefold distance. The law evidently is, that the weight and cost of the wire will increase as the square of the distance.

This difficulty is mitigated to a considerable degree by what is known as the "three-wire" system, first indicated by Mr. Brush in his patent No. 261,077, issued July 11, 1882, and developed in two different directions by Mr. Edison, in his patent No. 274,290, issued March 20, 1883, and by Mr. H. M. Byllesby, of the Westinghouse Co., in his patent No. 345,212, issued July 6, 1886, so that the loss can be reduced to three-eighths or even to five-sixteenths of what it would otherwise be by a moderate increase in the complication of the arrangements.

The outstanding loss has, however, led to the development of a radically new and very interesting system, known as the secondary or transformer system, chiefly represented in this country by the Westinghouse Electric Co.

The principle on which this system operates is indicated by Professor Brackett at pages 654 and 655 (June) of his article, and may be briefly stated by saying that if we have two conducting wires parallel to each other, and pass an interrupted or reversed (*i.e.*, alternating) current through one of them, there will be produced a similar, but always alternating current through the other, without there being any conducting contact at all between the wires.

This may be very beautifully shown by the following experiment:

We have upon a table an oval coil of fine copper insulated wire, through which is passing the rapidly reversing or alternating current obtained from a dynamo-machine which is working without a commutator. (Fig. 25, p. 199.)

If, now, we hold above it just such another coil, in whose circuit is included an incandescent lamp, this lamp will light up and glow to its full intensity as we bring the second coil near to the first, and will die out as the coil is moved away. This will operate just as well with a plate of glass between the two coils.

This action is greatly intensified by enclosing both coils in a mass of iron whereby magnetic influence is brought into play, and accordingly the converters or transformers used in this system are made, as will appear from inspection of Figure 24, by enclosing the two coils in a mass of iron made up of thin sheets, so cut that they can be sprung in, one at a time, around the coils.

The relative character of the currents in the two coils, depends substantially on their lengths and consequent resistance; that which is shorter and thicker having a current of larger volume and less pressure or electro-motive force, and that which is longer and thinner having less quantity or current strength and more electro-motive force or pressure.

Now a current of high electro-motive force and small quantity, can be carried a long distance on a small wire with very little loss.

Moses G. Farmer.

If, then, we pass this current through a coil of long fine wire, in a converter whose other coil is relatively short and thick, we shall obtain in the latter a current whose quantity is great and whose electro-motive force is low. In other words, we can thus transmit such a current as goes easily on a small wire, from the central station to the house where the lights are to be used, and there transform it into the kind of current most desirable for the operation of incandescent lights. In practice the Westinghouse Co. send out their currents with an electric pressure of one thousand volts or units of electro-motive force. A quantity of this current equal to one ampère, or unit of current strength, running through the fine wire of one of their converters will develop in the coarse wire a current of twenty ampères quantity but of only fifty volts pressure.

Such a current, however, would be just what was wanted to run twenty incandescent lamps in "parallel," series, which is the most convenient way, as each is then entirely independent of all the others.

The problems of cheap production of electric energy, of cheap and efficient regulators or arc lamps, of cheap and efficient incandescent lamps, and of economical methods of distributing the electric energy from the electric generators to the lamps having been solved so thoroughly, as has been here indicated, there seemed little yet to be desired. One thing, however, was *not* provided for, and that was the storage or accumulation of electric energy. The method of its production by the dynamo requires an absolutely constant activity and a literally sleepless vigilance. If the steam-engine stops or relaxes its speed, the light goes out or becomes dim; or if a belt breaks or slips off, or any part of the dynamo becomes disarranged, the light is gone in an instant and without warning.

This lack of storage capacity was often referred to, and was a serious reproach to the systems of electric lighting as compared with other methods of illumination. This reproach has been to some degree removed by the labors of M. Camille A. Faure, and of those who have followed up, and to a greater or less extent improved upon, his invention.

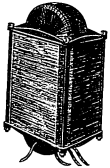
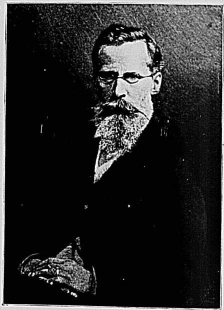


Fig. 24.—Converter or Transformer Used with an Alternating Current.

The "state of the art," as regards the storage of electricity prior to Faure, may be fairly expressed and summarized by a statement of what was done by Gaston Planté* in 1860.

This experimenter took a series of lead plates, immersed in a vessel containing diluted sulphuric acid, and coupled or joined them so that they were united into two groups, each alternate plate constituting one group and the intermediate plates being connected so as to form the other group. He then passed the current from a couple of battery cells, arranged in series, into this structure, by joining the positive pole of the battery to one of these groups and the negative pole to the other. When the action of the battery had continued for a long time, he found that on removing the battery, he could get an electric current from his two groups of lead plates; this current being opposite in direction to that developed by the battery and capable of yielding a greater flow for a shorter time. The knowledge already accumulated had explained the cause of this, which was as follows: The plates of lead, even before immersion, were coated with a film of oxide, and on immersion, at all events, would soon acquire a coating of sulphate of lead. The passage of the battery current between these plates would convert the oxide or sulphate, on one side into metallic lead, and on the other side into peroxide of lead.



Dr. William Crookes, F.R.S.

Now, metallic lead and peroxide of lead, as was well known, are substances well fitted to develop a galvanic current in the same way that such a current is developed by an ordinary galvanic battery made with plates, for example, of zinc and copper—the metallic lead taking the place of the zinc. There was, however, one important difference, that whereas in the zinc battery the zinc went into solution, in the lead battery nothing was dissolved, and therefore everything kept its original position, so that the original cycle of action could be indefinitely repeated. Planté, in fact, found that by repeatedly charging his lead plates from an ordinary battery, and discharging them again, and also by reversing the direction of the charging current, the capacity of his lead plates, or the amount of electric energy which they could be made to absorb and redevelop, was greatly increased. Indeed, the maximum capacity secured by this treatment was only reached after about six months of such charging and discharging. The reason of this also was not far to seek. By these repeated actions the surfaces of the leaden plates was corroded or honey-combed, and thus a greater amount of the material was in condition to be converted into metallic lead and peroxide by the battery current, and again to return to

* The news of Planté's death, early in June, is received while this article is in preparation.

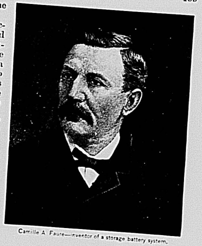
protoxide and sulphate during the discharge.

To obtain any considerable capacity in this way, however, required months of treatment (called "forming"), and a heavy expense for the charging currents, and soon after a battery was fully formed it began to deteriorate by a continuance of this corrosive action, which caused the porous material to scale off and the plates themselves to break up.

Planté's batteries were therefore of no commercial value, on account of their high cost and limited capacity.

Matters stood thus when, in 1881, the world was astonished by the accounts of what Mr. Faure had done in the way of improving this Planté secondary battery, into his electrical accumulator or storage battery.

His plan was a very simple one, but wonderfully effective. He took a quantity of litharge or of red lead, or a mixture of the two, both being oxides of lead, and making this into a paste with dilute sulphuric acid he coated the lead plates with this mixture. When the plates so coated were plunged in dilute sulphuric acid, and an electric current was made to pass between them, the thick coating of oxide-paste on one side began at once to be converted into a spongy mass of metallic lead, and on the other into a like spongy mass of peroxide of lead.



Camille A. Faure—inventor of a storage battery system.

In this way no time was lost in the "forming" process, and the capacity of the plates was very much greater in proportion to their weight than in the most perfectly formed plates of Planté. An improvement on this plan was made by Swan, of England, and others, which consisted in so perforating the plates that the paste of oxide would fill the apertures, like a series of rivets with conical heads, by which it would hold itself in position.

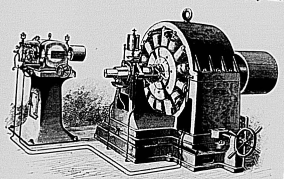


Fig. 25.—An Alternating Current Dynamo and Exciter.

The Faure and Swan patents and some others were taken out in this country by the Electrical Accumulator Co., who established a large factory at Newark, N. J., where these batteries have been made for many years. Figure 26 shows the interior of the

Fig. 26.—Room in the Factory of the Electrical Accumulator Company.
The groups of battery plates, such as are shown hanging from the travelling pulleys, are immersed in tanks of dilute acid, and charged by electric currents.

principal work-room in this factory. These batteries only *store electricity* in a metaphorical sense. What they actually do is to transform the active energy of an electric current into the potential chemical energy of separated chemical substances, which are able, by their reunion, to develop again an electric current such as that which produced them. In other words, the charging current each time decomposes the oxides and sulphates of lead formed by the chemical action of the battery during its discharge, so as to develop metallic lead on one set of plates and peroxide on the other. This having been done, this metallic lead by combining with oxygen and sulphuric acid on the one hand, and the peroxide by combining with hydrogen on the other, develop an electric current, as does any ordinary galvanic battery.

As these successive changes can be repeated an indefinite number of times, the effect and appearance are the same as if the electric current had been in fact stored up or accumulated in the storage battery.

A PAGAN INCANTATION.

By Hjalmar Hjorth Boyesen.

HAROLD OLYPHANT'S face was lighted up, by the glow of the fire, with a Rembrandt-like effect. You could see that it was a delicate face; perhaps you might even pronounce it a handsome one, but you might not discover at once, in that rosy illumination, that it was the face of a sick man. Whatever beauty it had was that of intelligence, refinement, and sensibility. It was not obtrusively handsome; nor obtrusively anything. Such gravely observant blue eyes, such thin, wavy, blond hair, such gently accentuated features, we see every day among professional men with a taste for scholarship; and, if we take the trouble to interpret them at all, we conclude that they indicate inherited cult-

Complainant's Exhibit "Eaton-Cross Letter of May 17, 1881." Feby. 28, '90. S. M. H., Exr.

May 17th.

Professor Charles R. Cross,
Massachusetts Institute of Technology,
Boston, Mass.:

Dear Sir—We send you by express this evening, so that you will receive it to-morrow morning, postpage prepaid, two Edison lamps and one Maxim lamp. The Maxim lamp is now manufactured in this city by one of our rival companies, to wit, The United States Electric Light Company.

Mr. F. H. Betts, of patent counsel to this company, will write you at once stating what opinion the company desires from you touching these lamps. May I ask you to keep the Maxim lamp where it will not be broken or injured, as we experience some difficulty in getting samples. As soon as you have finished the matter which Mr. Betts will write you about, will you kindly pack the Maxim lamp with great security and return it to me. The two Edison lamps you can retain in your possession, if you have any desire to do so.

I need hardly add that this subject is necessarily so confidential that it is desirable that you should keep it entirely secret.

Very truly yours,
S. B. Eaton,
Vice-President.

Complainant's Exhibit "Betts-Cross Letter of May 27, 1881." February 28, 1890. S. M. H., Exr.

FREDERIC H. BETTS,
CHARLES L. ATTERBURY,
C. WYLLES BETTS.
J. E. HINDON HYDE.

Law Offices of
BETTS, ATTERBURY & BETTS,
Equitable Building, 120 Broadway.

NEW YORK, May 27th, 1881.

PROF. CHARLES R. CROSS,
Massachusetts Inst. of Technology,
Boston, Mass.

DEAR SIR—I send you herewith copies of two patents of Thomas A. Edison for improvement in electric lighting apparatus, one No. 223,898, dated January 27th, 1880, and the other No. 227,229, dated May 4th, 1880. You will notice that the latter-named patent, though subsequent in date, is prior in point of application, the application for it having been filed April 21st, whereas that of the other was filed November 4th, 1879.

You will have sent to you a specimen of the electric lamp of the U. S. Electric Lighting Company, and we would like your opinion as scientific expert upon the following matters:

The first claim of the Edison patent, No. 223,898, is for "an electric lamp for giving light by incandescence, "consisting of a filament of carbon of high resistance "made as described, and secured to metallic wires, as "set forth."

The first question which arises in connection with the U. S. Company lamp is the following: Is the carbon which is made incandescent in the U. S. Co. lamp "a filament of carbon of high resistance?" You will notice that Edison says in his patent that previous to this invention light by incandescence had been obtained from RODS of carbon of one to four ohms resistance. It is clear that he means to say that such lamps were of low resistance, and that such "rods" were not "filaments." The question is, what is the resistance

of the carbon in the U. S. Co.'s lamp, and is such resistance, whatever it may be, a *high resistance* in the sense of the Edison patent? You will notice that Edison does not limit himself to any special amount of resistance, though he states that he has discovered that even a cotton thread properly carbonized and placed in a sealed bulb exhausted to one-millionth of an atmosphere, offers from one hundred to five hundred ohms resistance. I do not think that he intends to confine himself to lamps having *so high* a resistance. It has occurred to me that the only rule given by Edison's patent as a test of what is a "high resistance" is to determine whether a given lamp can or cannot be worked in large numbers in multiple arc without the employment of main conductors of large dimensions. In other words, is it not fair to say that a lamp which can be used in multiple arc with conductors of the ordinary dimensions of electrical wires is a lamp having a "high resistance," in the sense of the Edison patent? Please give this matter your early consideration and let us know whether the U. S. Company lamp is such a lamp.

The second question arises on Patent No. 227,229. You will notice that the first claim is for an electric lamp in which the metallic conductors pass through the glass, and around which the glass is melted. On examining the U. S. Company lamp you will notice that the metallic conductor passes through a blue tinted substance resembling glass. We should like to know whether this is really glass, and whether in that lamp the conductors do pass directly through the glass, and whether the glass is melted around them. We understand that it is claimed that the blue material is not glass.

I send you also a memorandum by Mr. Wilbur, one of the solicitors for the Edison Company, which will throw considerable light upon the Edison patents.

Yours truly,
FREDERIC H. BETTS.

Complainant's Exhibit "Wilber-Cross Memorandum of May 25, 1881." February 28, 1890. S. M. H., Exr.

MEMORANDUM OF POINTS

FOR

MR. BETTS' LETTER TO PROF. CROSS.

Prior to Edison's lamp, that is, prior to 1879, Mr. Edison alleges that the state of the art in incandescent electric lighting showed that the incandescing conductors used, either of platinum or of carbon, were of comparatively low resistance, never exceeding 2 or 3 ohms and generally not exceeding an ohm.

This is deducible from the dimensions given, method of treatment, etc. of carbons, as laid down in

Fontaine's Electric Lighting;
Higgs' Electric Light;
Sawyer's Electric Lighting.
And other works. And from the U. S. Patents of
Sawyer,
Woodward,
Farmer and others.

And from the English patents of Staite, King and others, epitomized in work of Sawyer noted above.

It is also shown by the fact that in all attempts to use a number of lamps, they were arranged in series, which necessitated low resistance in each, as the resistances of the circuit would be the number of the lamps × the resistance of one lamp, hence the resistance of any one must have been brought down as low as possible.

Mr. Edison holds that the use of incandescing conductors of such low resistance necessitated the use of conductors leading thereto of exceedingly great relative conductivity, which meant large mass, negativing the use of platinum therefor and requiring use of copper.

Copper could not be sealed directly into glass, owing to difference in coefficients of expansion of the glass and the copper.

Hence in the old lamps, the lamp globe had an aperture covered by a metal cap secured thereto by wax, etc., and through which the conductors passed into the lamp.

The large mass of conductor tended to conduct large amount of heat, destroying this sealing—by the unequal expansions of the glass and metal and the cements.

See Patent 205,144, Sawyer & Man.

This low resistance in the incandescing conductors rendered division on multiple arc system commercially or economically impossible, while if a system of central origin and distribution of currents for use in a great number of lamps were ever to be used, it must of necessity be a multiple arc system.

Mr. Edison reversed the practice as to resistance in the lamp, preferring to use incandescent conductors of an 100 ohm resistance and sometimes much higher, although 15 to 20 ohms and upward gave same advantages in a lesser degree.

Advantages of this are:

Division by multiple arc system practicable commercially.

The incandescing conductor being carbon of such high resistance, small platinum wires may be used as conductors thereto, which may be sealed directly into the glass, so that the globe or envelope is in substance one piece of glass, whereby vacuum is preserved.

The small mass of conductor used reduces conduction of heat so that there is little or no effect thereof at the point where the conductors ("leading in wires") are sealed into the glass, hence greater economy through rendering permanent the vacuum.

The incandescing conductor being of great resistance is of small mass, a mere filament, and elastic, so that it expands and contracts without fracture of itself or of its union to its clamps or holders.

By using incandescing conductors of such high resistance the mass of metal in what may be called the "mains," the conductors leading from the centre of generation of the currents may be proportionately diminished, whereby great economy in plant in fitting up a system is secured.

Mr. Edison would like Prof. Cross to investigate the subject and determine, if possible, what was the probable resistance of such incandescent electric lights as were described prior to 1879.

If they were of low resistance (up to say 2, 3, 4 or 5 ohms), is the use of incandescing conductors of high resistance relatively thereto (15 to 200 ohms), a practical advance in the art of subdividing the electric light and fitting the electric light for use as a domestic illuminant, taking into consideration the distribution of a current on a multiple arc system?

Is the Maxim U. S. lamp substantially identical in principle with the Edison lamp?

Z. F. Wilber.

May 25th, 1881.

Complainant's Exhibit Cross-Betts Letter of June 11, 1881. S. M. H., Exr.

Mass. Inst. of Technology.

Boston, June 11, 1881.

F. H. Betts, Esq.:

My Dear Sir—In reply to your letter of the 27th ult. I would say that I have considered several of the points referred to me, while regarding some of them I need a little more information.

1. The U. S. Co.'s lamp is undoubtedly a lamp of "high" resistance as compared with lamps of 1 to 4 ohms resistance. The resistance of the lamp sent is 43 ohms. I should say that beyond a doubt it is a high resistance lamp in the sense of the patent, although of less than the lowest resistance specifically mentioned therein, and less than those sent as types of Mr. Edison's own lamps, which have respectively between 3 and 4 times, and about 6 times the resistance of the U. S. Co.'s lamp. I have only measured two of Mr. Edison's lamps and therefore do not give the exact figures. I shall measure the others next week.

As to what is meant by the term high resistance as used in the patent of Mr. Edison, it seems best to me, unless there is some objection in getting up the case which does not immediately appear to compare the resistances of lamps made by him at or before the date of application with those used by others. If there are none used by others of over four, six, or ten ohms, there is no question that forty ohms, or even twenty ohms, would be a high resistance in the sense of the patent. In Mr. Wilber's note he asks me to determine the probable resistance of the earlier lamps. It will be an aid to me in this if you will send me a list of the various patents with their numbers and dates, so that I can look them up more readily. There are some of these referred to in Sawyer's book. I have not found Farmer's, however, nor Maxim's.

With regard to your suggestion that any lamp that that can be used with conductors of ordinary dimensions in multiple arc is a "high resistance lamp," a question would arise as to just what ordinary dimensions are, as the art of electric lighting has not been practised sufficiently long to determine what are standard sizes of conducting wires. Also what number shall be taken in multiple arc to constitute a large number? The terms are all indefinite, and there is room for argument on either side, but it seems to me that if possible the comparison of the earlier with the latter resistances is best. In any case the lamp of the U. S. Co. which was sent me is, in my opinion, such a lamp.

2. With regard to the other point, I have examined the U. S. Co.'s lamp as far as is possible without cutting it in pieces. The material through which the platinum wires pass *seems* to be vitreous in its nature and melted around the wires. I can determine more about it if you think I had best cut one of the two Maxim lamps sent me. One of these has the carbon broken, which is of course the one that I should break. As to the real nature of the blue substance, we cannot be certain except by a chemical analysis. You probably have a chemist in your employ who could analyze this, though if you wish me to testify regarding it I can get the analysis made for me. Please advise me.

As to the last two points mentioned by Mr. Wilber, (1) the use of incandescing conductors of high resistance is a practical advance, and (2) the Maxim U. S. lamp is substantially identical in principle with the Edison lamp.

I am, yours very truly,

CHAS. R. CROSS.

Complainant's Exhibit, "Eaton-Cross Letter of June 16, 1881," February 28, '90. S. M. H., Exr.

JUNE 16th.

PROFESSOR CHARLES R. CROSS,
Massachusetts Institute of Technology,
Boston, Mass.:

DEAR SIR—Herewith I send you by express two volumes of United States electric light drawings and specifications. These are sent pursuant to a request made in your letter to Mr. Betts, dated June 11th, wherein you ask for a list of patents, with numbers and dates. In order to save the delay of procuring fresh copies for you, we send these volumes, which contain every patent as yet issued touching the subject of electric lights. Will you kindly return these two books before the first day of July?

The English patents, which can be found in the Boston Public Library, are as follows:

ENGLISH PATENTS INCANDESCENT ELECTRIC LIGHTS.

No.	9,053, of 1841	De Molens
"	10,919, of 1845	King (Starr)
"	12,212, of 1848	Staite
"	13,302, of 1850	Shepard
"	14,198, of 1852	Roberts
"	3,809, of 1872	Konn
"	441, of 1875	Kosloff
"	970, of 1875	Konn
"	2,477, of 1878	Werderman

Allow me to suggest that you had best get the broken Maxim lamp; also that, as regards the real nature of the blue substance, you had best have a chemist in your own employ analyze it, and to do so in such a way that you can testify as regards it hereafter as of your own knowledge.

May I request you to give this investigation your early attention as our Board of Directors are getting impatient to have a decision reached in the matter, and if we do anything we desire to get under way before Mr. Betts sails for Europe next month.

Very truly yours,
S. B. Eaton,
Vice-President.

Complainant's Exhibit Cross-Eaton Letter of June 23, 1881. S. M. H. Exr.

Mass. Inst. of Technology,
Boston, June 23, '81.

S. B. Eaton, Esq.,

My Dear Sir—I return to-day by Adams' Express the two volumes of patents.

I have just forwarded a letter to Mr. Betts regarding the matter under discussion, stating my conclusions.

Very truly yrs.,
Chas. R. Cross.

Complainant's Exhibit "Cross-Betts Letter of June 23, 1881." Feby. 27, '90. S. M. H., Exr.

Mass. Inst. of Technology,
Boston, June 23, 1881.

F. H. Betts, Esq.:

My Dear Sir—I have examined the American patents, and the various works on electric lighting, with reference to the matter of the resistance of incandescent lamps, previous the date of Mr. Edison's patent. I have not yet looked at the English patents, prefering not to delay longer before writing to you. I will look them over to-morrow or next day.

From all the statements that I can find, or calculations that I can make based upon these statements, I should say that the lamps previous to Mr. Edison's patent had a resistance of not over five ohms, and generally much less than this. I infer this from the statements made regarding the size of carbons, in which they are called "pencils," "small rods," &c. Also from the measured dimensions as given in the drawings of said lamps. In Sawyer's book on Lighting by Incandescence, p. 90, the resistance of his lamps is state to be 25/100 ohms.

The only statement regarding a higher resistance is in Sawyer's book and also in his Patent No. 205,303 (Distribution of Lamps) the resistance of lamp is called 10 ohms when *hot*, "practically *nil*" when cold, "practically *nil*" being, I suppose, 1/4 ohm.

But the effect of heat on carbons is (unlike its effect on metals) to *diminish* its resistance, this diminution being according to Matthieson about 12 per cent. when the carbon is raised to incandescence. The increase of resistance from heating of the metallic conductors could not be great in any lamp that could be practically used, so that I am inclined to think that the number, 10 ohms, is stated at a venture. Mr. Edison could probably solve this question immediately from his practical knowledge.

By the way, can the Sawyer Patent No. 205,303 for distribution of lamps be held? The principle on which any resistances should be arranged for maximum effect has been familiar to every scientific man for the last forty years.

Compared with all these actual resistances (up to 5 ohms) that of the Maxim lamp is certainly "high" beyond a question. The only point regarding which an objection could be made is that 100 ohms is the lowest resistance mentioned in the Edison patent. On the other hand, Mr. Edison here describes for the first time (if I am right) a process by which a carbon *filament* can be made practically. No carbon *rod*, of say 20 ohms resistance upward, could readily be made to emit light by incandescence by any current that could be practically and economically employed. At least this I should judge to be case. Hence is not Mr. E. justified in claiming that even 20 ohms would be a high resistance under the terms of his patent? If only 5 ohms as a maximum were used before, if Mr. Edison's process is a new one giving the possibility of making high resistance carbons, it seems to me that even though the ratio of 5 to 20 is the same as 20 to 100, the claim can readily be held. Here your suggestion that the possibility of using lignts in multiple arc is an index of their "high" resistance, in the terms of the patent, might be available. But the Maxim lamp has a resistance of 40 ohms.

As to the sealing of the Maxim lamp. I have entrusted an analysis of the blue and black substances used in sealing to a competent chemist, who will give me his report by the close of this week or first of next. Meanwhile I will say, that from a careful examination of the fragments of the material after cutting it, we are pretty well convinced that it is a glass or an enamel. The blue is probably colored with copper, the black with iron and manganese. The chemist thinks it may be a borax glass for easy fusion. He thinks the only possible claim that could be made is that it is "enamel," which is a kind of glass. As to this last point,

I have not looked up the chemistry of glass, thinking it hardly necessary just yet. The Encyclopædia Brittannica and Appleton's Encyclopedia both speak of enamel as a glass, and the latter classifies it under the kinds of glass. The conducting wires are sealed into the glass as in Edison's lamp. It seems to me, then, that the Maxim lamp and Mr. Edison's are substantially the same thing.

I believe that I have touched upon all the points mentioned by you. I will write again as soon as I hear from my chemist.

I am,

Yours very truly,

Chas. R. Cross.

Complainant's Exhibit "Cross-Betts Letter of June 24, 1881." Feby. 28, 1890. S. M. H., Exr.

BOSTON, June 24, '81.

F. H. BETTS, ESQ.:

MY DEAR SIR—I have to-day looked over the various English patents relating to electric lighting by incandescence. I find nothing to change my opinions as expressed in my letter to you. The only light about whose very low resistance there is any question is Werdermann's, but in this incandescence proper as distinct from a very minute voltaic arc is distinctly disclaimed.

Very truly yrs.,
CHAS. R. CROSS.

Complainant's Exhibit "Cross-Betts Letter of June 27, 1881." Feby. 28, 1890. S. M. H., Exr.

MASS. INST. OF TECHNOLOGY,
BOSTON, June 27, '81.

F. H. BETTS, ESQ.:

MY DEAR SIR—Mr. Sharples, the chemist, who has examined the material surrounding the platinum wires in the Maxim lamp, writes as follows:

"As near as I can make out, from the very limited amount of material at my command, the blue substance on the lamp is merely an ordinary enamel, containing silica, lead, soda, tin and a little coloring matter.

"Enamels are mere glasses rendered apaque by tin, or some other substance, and so far as their use in this place is concerned, are exact equivalents of ordinary glass."

I am,
Yours very truly,
CHAS. R. CROSS.

Complainant's Exhibit Notes on Geissler Tubes. S. M. H. Exr.

1. *All gas and vapors are non-conductors.*

"At no degree of exhaustion is air a conductor." (*Ganot*, Physics, 13th Ed. 1890, p. 930).

The specific resistance of "air" is "practically infinite."

(*Everett*, Units & Phys. Consts., 1886, p. 165).

"Under all pressures and at all temperatures gases and vapors are perfect insulators."

"To suppose as is generally done that very rarefied gases or gases at very high temperatures are conductors, is a mistake due to confusion between resistance to disruptive and conductive discharges." (Luvine, Nature Vol. xxxiv., p. 516, 1886.)

Air is "one of the best, although not the strongest of insulators." (*W. Thomson*, Electros. & Mag., 1872, p. 217).

"If any conduction were now to take place through the air between the tube and the rod it would be indicated by the electrometer. No conduction however could be observed even after the lapse of a quarter of an hour and when hot air and steam were blown through the tube." (*Maxwell*, Elem. Elec., 1881, p. 115).

"Even mercury vapor does not conduct electricity." "The wire was connected with the electrometer, but no evidence of conduction of electricity could be observed even when the mercury was boiling briskly and its vapor was being condensed on the wire." (*Ib.*, p. 115).

"We have hitherto obtained no evidence of the conduction of electricity through air at the ordinary pressure and temperature, under a feeble electromotive force."

"It is probable that if we could support an electrified body on a perfectly insulating stand, so that it

could lose its charge only by conduction through the air, it would never lose its charge." (*Ib.*, 116).

"There is no true conduction through either gases or vapors; in other words a substance in this condition seems to behave as a perfect insulator—perhaps the only perfect insulator there is. Not even mercury vapor is found to conduct in the least." (*Lodge*, Nature xxxvii., p. 12, 1887).

2. *Spark through gases is disruptive not conductive.*

"Opposed to insulation is discharge." "That which is called simply *conduction* involves no chemical action and apparently no displacement of the particles concerned."

"A third mode, namely that by sparks or brushes, may because of its violent displacement of the particles of the *dielectric* in its course, be called the *disruptive* discharge." (*Faraday*, Exp., Res., p. 418, 1838).

"The next form of discharge has been distinguished by the adjective *disruptive* as it in every case displaces more or less the particles amongst and across which it suddenly breaks." (*Ib.*, p. 433).

"If the electro-motive force acting at any point of a dielectric is gradually increased, a limit is at length reached at which there is a sudden electrical discharge through the dielectric generally accompanied with light and sound. The dielectric, if solid, is often pierced, cracked or broken, and portions of it are often dispersed in the form of vapor. This phenomenon appears to be analogous to the rupture of a solid body when exposed to a gradually increasing stress. This analogy is so complete that we may make use of the same terms in describing the behavior of media under the action of electro-motive force as we apply to bodies under the action of stress. Thus electro-motive force and electric displacement correspond to ordinary force and ordinary displacement; the electro-motive force which produces disruptive discharge corresponds to the breaking stress. Conduction or the transmission of electricity corresponds to permanent bending." (*Maxwell*, Elem. Elec., p. 110, 1881).

"Induction across a non-conducting medium is always accompanied by a mechanical stress upon the medium. If this stress is very great the non-conducting medium will suddenly give way and a spark will burst across it. Such a discharge is called a 'disruptive' discharge." If a charged ball be lowered toward a metal plate lying on the ground "the more the ball is lowered down the greater is the accumulation of the opposite kinds of electricity on each side of the layer of air and the stress across the layer becomes greater and greater until the limit of the dielectric strength is reached; the air suddenly gives way and the spark tears a path across." (*S. P. Thompson*, Elec. and Mag., pp. 235-6, 1889).

"Chief amongst the mechanical effects of the disruptive spark discharge is the shattering and piercing of glass and other insulators. The dielectric strength of glass, though much greater than that of air, is not infinitely great." (*Ib.*, p. 237).

"If the applied slope of potential overstep a certain limit, fixed by observation at something like 33,000 volts per linear centimetre for common air, the molecules give way, the atoms with their charges rush across to the plates and discharge has occurred. The number of atoms thus torn free and made able to convey a charge by locomotion is so great that there has never been found any difficulty in conveying any amount of electricity by their means. In other words, *during* discharge the gas becomes a conductor, and being a conductor by reason of locomotion of atoms, it may be called an electrolytic conductor." (*Lodge*, Mod. Views Elec., p. 125, 1889).

"Wheatstone concludes from his researches that the electric light (of the spark) is the result of the volatilization and the ignition (but not the combustion) of the ponderable material of the conductor." (*Mascart*, Elec. Stat. II., 150, 1876).

See also *Fleming Jenkin*, Elec. and Mag., p. 92, 1873.

3. *Spark discharge does not follow Ohm's law.*

A. *Because elec. transmission increases as amount of matter decreases.*

"The electro-motive force necessary to produce the discharge diminishes, while the pressure is reduced from that of the atmosphere to that of about 3 millimetres of mercury." (Expts. on Rarefied Air, *Maxwell*, "Elem. Elec.," p. 113, 1881.)

"What is called 'the dielectric strength' of a gas—that is, the strain it can bear without suffering disruption and becoming for the instant a conductor—depends partly on the nature of the gas and very largely on its pressure. Roughly one may say that a gas at high pressure is very strong, a gas at low pressure very weak." "In a rare gas there are fewer molecules between the plates to share the strain between them." (*Lodge*, Mod. Vs., 126.)

"If 40,000 volts per centimeter break down ordinary air, 40 volts per centimeter ought to be enough to effect discharge through air at a pressure of about ¾ of a millimeter of mercury; and at a pressure of 50 atmospheres 2,000,000 volts per centimeter should be needed." (*Lodge*, *Ib.*, p. 126.)

"Thin layers of air oppose a proportionally greater resistance to the piercing power of the spark than thick layers and possess greater dielectric strength." "In rarefied air the spark is longer. Snow Harris stated that the length of spark was inversely proportional to the pressure." But according to Gordon, at lower pressures than 11 in. mercury "a greater diff. potential must be used to produce a spark than that which would accord with Harris' law." (*S. P. Thompson*, Elec. and Mag., 244, 1889).

"The length of the spark differs in different gases, being nearly twice as long in hydrogen as in air at the same density and longer in air than in carbonic-acid gas." (*S. P. Thompson*, *loc. cit.*, p. 244).

"When the discharge either of a coil or electrical machine is passed through a tube or other vessel connected to an air pump it is found that as the pressure diminishes the length of spark which can be obtained increases." (*Gordon*, Elec. and Mag. II., 54, 1880).

"My results agree very well with Sir Wm. Thomson's, for he writes: 'Greater electro-motive force per unit of length of air is required to produce a spark *at short distances than at long.*' For the words in italics I substitute 'at low pressures than at high.' We may then both write 'with a low 'air resistance' than with a high one,' or 'with a few air particles between the points than with many.'" (*Gordon, loc. cit.*, p. 62).

"The length of spark given by a battery at ordinary atmospheric pressures in the following gases is the longest in the order in which they are enumerated—hydrogen, nitrogen, air, oxygen, carbonic acid—it being nearly twice as long in hydrogen as in air. The spark does not appear to be dependent on the specific gravity of the gas." (*Gordon*, l. c., p. 64).

B. *Because the fall of potential in the circuit is not proportional to the resistances of its several parts.*

"By Ohm's law, the potential along a conductor falls regularly along the resistance, and, therefore, if the vacuum tube had been an ordinary conductor there would have been a uniform fall of potential along the whole circuit consisting of tube A B and resistance B C; and the line L M C would have been straight from L to C; as it was, however, it was found that however much the slope of the part M C varied that of L M, representing the fall of potential along the tube remained constant. This shows that the discharge is not a case of true conduction, but that even at the lowest pressure it is disruptive." (*Gordon*, loc. cit., p. 82).

Gordon's own investigation "confirms Mr. De la Rue's discovery that disruptive discharges do not obey Ohm's law." (*Gordon*, l. c., 58).

"Electric sparks thus produced are said to overcome the resistance of the air, but this resistance has nothing in common with the resistance which is the subject of Ohm's law. The laws according to which sparks pass and brushes, as they are called, form on points electrically charged, must be separately studied."

"These glass tubes (Geissler's tubes) contain highly rarefied gases, and electrodes leading through the glass are employed as part of the circuit. If a galvanometer and an electric battery form part of the circuit, no current will be observed until perhaps two hundred

cells are employed." (*F. Jenkin*, Elec. & Mag., 93, 1873).

"These (discharge) currents are alternate not only in direction but also in time, and no one of them is produced until after the complete extinction of its predecessor." *Spottiswoode*, (*Gordon*, loc. cit., p. 72).

The discharge in the vacuum tube "cannot be considered as a current in the ordinary acceptation of the term, but must be of the nature of a disruptive discharge, the molecules of the gas acting as carriers of electricity." *De la Rue & Miller*, (*Gordon*, loc. cit., p. 85).

Complainant's "Exhibit Howell's Statement No. 1." July 8, 1890. S. M. H., Exr.

Lamps having filaments made of Lamp Black and Coal Tar, in accordance with Edison's Patent No. 223,898.

Tested May 1st, 1890. J. W. H.

Number.	Diameter all 5" long.	Form.	Candles.	Volts.	Ampere.	Watts per Candle.	Resistance, Cold.	Resistance, Hot.
1	.015	Spiral.	12	62.	1.10	5.68	93.	56.3
2	.015	"	12	65.	1.135	6.15	97.	57.2
3	.010	"	8	83.	.565	5.86	255.	146.9
5	"	"	"	82.5	.66	6.8	198.	125
6	"	"	"	74.25	.625	5.78	212.	118
8	"	"	"	80.5	.60	6.03	238.	134
9	"	"	"	83.75	.605	6.33	224	138
10	"	"	"	85.5	.60	6.41	237.	142
12	"	"	"	82.	.58	5.94	234.	141
13	"	"	"	82.	.605	6.20	225.	135
14	"	"	"	81.5	.6325	6.44	223.	128
15	"	"	"	81.	.6125	6.20	228.	132
16	"	"	"	81.	.60	6.07	233.	133
18	"	"	"	85.5	.55	5.87	234	155
27	"	Loop.	"	80.25	.58	5.81	243.	138
28	"	"	"	86.	.56	6.02	273.	153
29	"	"	"	84.	.55	5.77	277.	152
30	"	"	"	81.75	.57	5.82	262.	143
31	"	"	"	83.	.56	5.81	270.	148
19	.007	Spiral.	6	103.25	.35	6.02	450.	295
20	"	"	"	114.	.32	6.08	550.	356
21	"	"	"	98.25	.35	5.73	430.	280
22	"	"	"	96.75	.35	5.64	409.	276
24	.006	"	5	131.25	.25	6.56	910.	525
23	.017	"	14	59	1.25	5.26	81.	47.2
26	"	"	"	59.75	1.15	4.91	84.	51.9

Complainant's "Exhibit Howell's Statement No. 2," July 8, 1890. S. M. H., Exr.

Lamps having Filaments made of Lamp Black and Coal Tar, in accordance with Edison's Patent No. 223,898.

Date, April, 1890.	Filaments made.	Diameter. All are 5" long.	Broken before carbonization.	Broken during carbonization.	Carbonized O. K.	Broken before exhaustion.	Broken during exhaustion.	Finished lamps broken.	
2	3	.015	1		2				
3	4	.010	2		2				
4	4	.010	1		3				
7	7	.010		1	6	1			
8	4	.010			4	2			Broke two trying to silver solder wires.
9	2	.010			2			2	One broken in glass room.
17	2	.010			2	1		1	
18	2	.007		1	1				Shrunk tight on mandrel.
19	6	.007		3	3	1			Fused copper helix in furnace.
21	2	.007			2				
21	2	.017		1	1				
23	3	.006		1	2			1	Broken in photometer; was spotted.
24	2	.010			2	1			
25	5	.010			5	1			
26	3	.017	1	1	1				
Totals	51		5	8	38	7		4	27 good lamps.

May 1st, '90. J. W. H.

Complainant's Exhibit "Deshler's Test of Howell's Lamps." S. M. H., Exr.

Date.		A. M. on	A. M. off	P. M. on	P. M. off	Hrs. per day.	Total hrs.	Candle hrs.	Power % C. P.	
Apr.	22			2-55	6-00	3-05				Average amperes .08786
"	23	7-10	12-00	12-35	"	10-15	......	....	....	
"	24	10-09	"	"	"	7-16				
"	25	7-10	"	12-32	"	10-18				
"	26	7-15	"	12-35	4-30	8-40				
"	28	7-11	"	"	6-00	10-14				
"	29	7-10	"	"	3-55	8-10	......	....	{91.963	
"	30	7-15	"	"	6-00	10-10	......	62¾		Average amperes .09583
May	1	7-12	"	12-33	"	10-15	68-06			
"	2	7-11	"	12-35	"	10-14				
"	3	7-10	"	"	4-30	8-45				
"	5	7-11	"	"	6-00	10-14				
"	6	7-12	"	"	"	10-13				
"	7	7-10	"	12-32	"	10-18				
"	8	7-12	"	"	"	10-16				
"	9	7-15	"	12-35	"	10-10				
"	10	"	"	"	4-30	8-40				
"	12	7-40	"	12-32	6-00	9-48				
"	13	7-15	"	12-35	6-00	10-10				
"	14	"	"	"	"	10-10	......	....		
"	15	7-12	"	12-32	"	10-16	......	182¾	{90.625	Average amperes .09583
"	16	"	"	12-33	"	10-15				
"	17	7-13	"	12-35	4-30	8-42				
"	19	7-11	"	12-30	6-00	10-19				
"	20	7-15	"	12-35	"	10-10				
"	21	"	"	"	"	10-10				
"	22	"	"	"	"	10-10				
"	23	7-10	"	"	"	10-15				
"	24	7-12	"	"	4-30	8-43				
"	26	7-10	"	12-32	6-00	10-18				
"	27	7-15	"	12-31	"	10-11				
"	28	7-12	"	12-35	"	10-13				
"	29	7-15	"	"	"	10-10				
"	31	7-12	"	"	4-30	8-43	325-56			
June	2	7-10	"	12 33	6-00	10-17				
"	3	7-13	"	12-35	"	10-12				
"	4	7-13	"	12-32	"	10-15	......	....	{92.708	
"	5	7-15	"	12-21	"	10-21	......	355¾		Average amperes .09633
"	6	"	"	12-35	"	10-10				
"	7	7-15	"	12-35	4-30	8 40				
"	9	"	"	"	6-00	10-10				
"	10	"	"	12-32	"	10-13				
"	11	7-12	"	12-35	"	10-13				
"	12	7-15	"	"	"	10-10				
"	13	"	"	"	"	10-10				
"	14	7-13	"	12-30	4-30	8-47				
"	16	7-15	"	"	6-00	10-15				
"	17	"	"	12-33	"	10-12				
"	18	7-13	"	12-35	"	10-12				
"	19	"	"	"	"	10-12				
"	20	7-15	"	"	"	10-10				
"	21	"	"	12-20	4-30	8-55				
"	23	"	"	12-35	6-00	10-10				
"	24	7-13	"	"	"	10-12				
"	25	7-15	"	12-32	"	10-13				
"	26	"	"	12-35	"	10-10				
"	27	7-14	"	"	"	10-11				
"	28	7-13	"	"	4-30	8-42				
"	30	"	"	"	6-00	10 17	575-25			
July	1	7-10	"	12-32	"	*9-33				
"	2	"	"	12-31	"	10-19	......	....	....	*off 45'
"	3	7-15	"	12-28	1-13	5-30	600-47	600¾	{85.000	Average amperes .70100

C. DESHLER.

Complainant's "Exhibit Jackson's Statement, No. 1." S. M. H. Exr.

#8 Cotton thread	#1	452	ohms, cold
	2	424	"
	3	466	"
	4	518	"
	5	394	"
	6	400	"
#10 Cotton..................	#7	340	"
	8	890	"
	9	1500	"
#20 Cotton	#10	1100	"
	11	1100	"
	12	900	"
	13	836	"
#60 Cotton..................	#14	1670	"
#100 Cotton	#15	2240	"
	16	1540	"
Linen thread	#17	170	"
#40 Cotton, tarred	#18	390	"
#10 Cotton, tarred..........	#19	190	"
	20	340	"
#10 Cotton, tarred and wound with copper wire	#21	283	"

Complainant's "Exhibit Jackson's Statement No. 2."—S. M. H., Exr.

Number.	C. P.	V.	Amp.	Res.	Eff.
					w. per c.
1	8	158	.475	333 ohms	9.4 w.
2	8	141	.50	282	8.8
3	10	165	.535	308	8.8
4	8	164	.485	338	9.9
5	8	136.5	.52	262	8.8
6	8	136	.515	264	8.75
7	8	124.6	.55	226	8.5
8	8	237	.395	600	11..
9	-	---	----	---	--
10	8	216	.302	691	8.4
11	8	216	.31	700	8.4
12	8	218	.365	597	9.9
13	8	198	.375	528	9.3
14	3	122.5	.19	645	7.7
15	4	241	.155	1555	9.3
16	3	174	.165	1055	9.6
17	8	90	.84	107	9.4
18	5	109.5	.40	274	8.8
19	8	93	.71	131	8.2
20	8	125.5	.555	226	8.7
21	8	111.2	.59	188	8.2

Complainant's Exhibit, "Eaton Tribune Interview of August 13, 1881." S. M. H., Exr.

NEW YORK DAILY TRIBUNE.

Saturday, August 13, 1881.

ENJOINING THE MAXIM LAMP.

Major Eaton, Vice-President of the Edison Electric Light Company, was asked last night if the report was correct that the Edison Company had obtained an injunction in Paris, France, against the United States Electric Light Company, preventing that company from exhibiting the Maxim lamp at the Paris Electrical Exposition.

"The report is true," said Major Eaton. "We have long been advised by our patent lawyers that Mr. Edison's patents gave him an exclusive control of incandescent lighting, and that other analogous systems were infringements which he could at any time suppress by going into Court. But until now we have never taken the trouble to assert our rights. Some days ago we cabled to Mr. Edison's agents in Paris to begin a suit for infringement against the Maxim lamp, and yesterday we received word that a suit had been begun and the United States Company enjoined by the French Courts from exhibiting their light in France. French Courts grant these injunctions with great reluctance, but our case was so clear there was no trouble. In due time we shall begin other suits there, and also enforce our rights in this country."

Complainant's Exhibit "Eaton World Interview of August 21, 1881." S. M. H., Exr.

THE NEW YORK WORLD.

Sunday, August 21, 1881.

THE MAXIM LIGHT AT PARIS.

The following dispatch was received last night from Paris, at this office:

TO THE EDITOR OF THE WORLD, NEW YORK:

"I am authorized to deny the report cabled to the United States, that the exhibition here of the Maxim Light Company has been stopped by the seizure of the apparatus, or by any other proceedings taken in the interest of the Edison Company. The exhibition is thoroughly organized, and is now on view daily at the Palais de l'Industrie.

R. WHITEING.

"Paris, August 20".

The above authoritative despatch from the resident correspondent of The World seems to be final as to the point to which it relates. Mr. Flint, the President of the Mexican Electric Light Company, not being found at his office, the tenor of the dispatch was communicated to Major Eaton, President of the Edison Electric Light Company, who seemed much surprised and said finally, "I don't understand this at all. The rights in the Edison lights for the City of Paris are owned by a syndicate of French bankers. The Edison Company are bound by the terms of the sale to maintain their full rights, and as there are only three incandescent lights now on exhibition, the Edison, the Swann of England, and the Maxim, and as we claim that the latter two were stolen from us, we began suit against the United

States Company in the French Courts. That is, we began this suit by our agents. The French law provides that not only shall an infringement of a patent not be sold but it shall not be exhibited. Under this law we obtained a decree, and as a result a process—something akin to an injunction was issued. In France they seize what they call the offending goods, and in this way Maxim's lights were locked up by what we would call sheriff's process. You must not imagine that I am an authority on French patent law, but I am telling the thing to you as I understand it myself. It was explained to me by a gentleman who came in here just after we got the news, and I tell it to you as I understand it. In reference to the despatch of which you speak I can only say this: We are in constant communication with Paris; our agents are fully alive to the importance of anything like a release of the goods, and certainly would have telegraphed us had any change been made. Besides, there is now in this city a gentleman who arrived by the last French steamer, and who is a member of the French syndicate. Most assuredly he would have been notified had any change in the position of affairs taken place. There is one thing which may possibly explain the seeming confusion of news. Maxim has in Paris two lights, the arc and the incandescent carbon. The first we have nothing do with, as we do not manufacture anything of the kind and lay no claim to such a form. The second we do claim and believe that all persons who manufacture it have stolen it from Mr. Edison. Now it is quite possible that the arc light shown by Mr. Maxim may be burning while the incandescent carbon is in possession of the French officer equivalent to a sheriff. However, about this I do not know positively, but I shall just as soon as I can get an answer by telegraph across the water. I cannot conceive it to be possible that any release of the goods could have been made without our knowing of it; and that the incandescent burners were seized and locked up under a decree granted by a French Court in a suit for infringement of patent right brought by our agents, I am as certain as I am that I am talking to you."

Complainant's Exhibit "Times Article of April 27, 1882." S. M. H., Exr.

THE NEW YORK TIMES,

New York, Thursday, April 27, 1882.

ELECTRIC LIGHT MONOPOLY.

THE EDISON COMPANY JOINS THE GRAMME COMBINATION.

A Powerful and Rich Organization—The Ownership of all Electric Light Patents Claimed—Vice President Eaton's Statement.

One of the most gigantic monopolies of the age has been created by the union of the Edison Electric Light Company with the Gramme Electrical Company on the 22d of last month. By this combination the several large companies that claim to control all of the patents applying to existing systems of lighting by electricity are formed into one monster organization. The Gramme Company was established in the latter part of April, 1881, and, prior to the joining of the Edison, Company, was composed of the American Electric Company, of New Britain Conn., the Brush Electric Company, the Fuller Electrical Company, the Jablochkoff Electric Light Company, the United States Electric Lighting Company and the Weston Electric Company. All of these companies were possessed of valuable patents, and were supposed to be backed by ample means. So strong, in fact, did the Gramme Company consider itself that it announced by circular that the patents owned by its members covered "the fundamental principles involved in all the existing systems of lighting by electricity and cannot be successfully avoided by outside companies." As the Edison Company was at that time one of the "outside companies," it might reasonably be inferred that the language of the circular was directed at that

company as well as to the smaller and much less powerful organizations.

The first annual meeting of the Board of Trustees of the Gramme Electrical Company was held at the company's office in the Boreel Building, Broadway, on Tuesday afternoon and yesterday morning, and the first annual meeting of the stockholders of the same company was begun yesterday afternoon. Mr. Henry I. Hoyt, President of the Gramme Company, presided during the former meeting, and Major S. B. Eaton, Vice-President of the Edison Electric Light Company, was Chairman of the stockholders' meeting. The character of both meetings was more conversational than otherwise, the objects, prospects and internal policy of the great organization being informally discussed. It was announced that, among other topics brought up for consideration, was the best methods to be pursued to gain public confidence in a responsible system of electrical lighting. The stockholders' meeting was attended by the following named gentlemen: Henry I. Hoyt, W. H. Appleton, R. B. Minturn, C. R. Flint, Col. R. R. Hazard, the Hon. M. D. Leggett, George W. Stockley, Major S. B. Eaton, C. Goddard, W. Parker, J. J. Skinner, W. M. Ivins, A. B. Chandler, C. A. Cheever and G. W. Hebard. The meeting was adjourned until 11 o'clock to-day, when it is expected there will be an election for officers.

Prior to this meeting it had not been generally known that the Edison Company had joined the Gramme Company, and upon the *Times*' reporter expressing some surprise that such should be the case, President Hoyt promptly replied: "Oh, yes; the Edison Company are with us."

"How was the union brought about?" was the very natural inquiry.

"Well," said President Hoyt, "the Edison Company could not very well do anything else than come in. You see, the Gramme Electrical Company own patents that cover every system of electric lighting, and there is no company that would care to stand out against us." Mr. Hoyt then entered into an explanation of the extent, power and purposes of the Gramme Company. He said that public confidence had been shaken in the electric light enterprises by the organization of "wild cat" stock companies, whose only object seemed to be to foist a lot of worthless stock upon a gullible public. Such companies were being organized all over the country. They owned no patents and were for the most part entirely irresponsible. Frequently they would buy machines from other companies merely to place on exhibition in order to secure a sale of their stock. "Why, sir," exclaimed Mr. Holt indignantly, "I have even had men come to me and ask to borrow dynamo electric generators to exhibit in the offices of the so-called electric light companies. Now, one of the chief objects of the Gramme Company is to stamp out all such fraudulent concerns. I have here a list of 40 or 50 of them, and the agents of our company keep themselves thoroughly posted as to the movements of all such speculative enterprises. We shall endeavor to break up their practices as soon as possible. It is absolutely necessary to the success of the legitimate electric light companies that the public should be fully informed regarding the worthlessness of many enterprises in which they are invited to invest money." Other officers of the Gramme Company were enthusiastic in their assertions of what the extensive and influential organization proposed to do. It was believed that the several companies belonging to the Gramme would reap untold advantages. In the first place, uniformity of prices will be secured, more perfect harmony of action will exist, and the necessary litigation between the companies will be simplified and made much cheaper. As for outside companies, it was declared that active steps will be taken to wipe out every electric light company in the country unless they should have something new and worthy of consideration in the way of electric light. The statement is also made that there is probably not a patent lawyer in the country of any prominence or special ability who is not engaged in the interests of the Gramme Company.

Major S. B. Eaton, the Vice-President of the Edison

Electric Light Company, was called upon at his office by a "Times" Reporter and asked if he would explain why the Edison Company joined the Gramme Electrical Company. He replied: "As long ago as last August a committee representing the Gramme Company and a committee from our own company were appointed to confer as to our joining the Gramme Company. Those committees continued their conference until recently, when, agreeable arrangements having been made satisfactory to the Gramme Company and its constituents we, on March 22d, became members of that organization. As regards the Gramme Company's patents, our present attitude is just what it has always been, viz., that we do not use the Gramme Machine, and that the Edison Machine in no sense whatever infringes the Gramme patents. Our reasons for joining the Gramme Company had nothing to do with the Gramme patents. We desire to avail ourselves of the advantages of a business organization controlled by people engaged in enterprises similar to ours, and united to promote harmony, uniformity of prices, and simplicity of litigation, and also to prevent the public from being imposed upon by new compaines without patents and without integrity. A very important consideration with us was that we wished to avoid being hectored by every new company that unprincipled parties disposed to steal our inventions might get up. Such companies spring up daily. It is one of the functions of the Gramme Company to strangle all such organizations, and we would gladly join the Gramme Company just for that one convenience of having somebody else take off our hands the tiresome and expensive task of putting so many other combinations to death."

"Could the Edison Company have prosecuted its business successfully had it remained independent of the Gramme Company?"

"There is no reason at all why it should not have been able to do so. The Edison Company is devoted exclusively to incandescent lighting, and all of the other companies composing the Gramme combination are, with a single exception, devoted exclusively to arc lighting. The patents possessed by the arc lighting companies have nothing whatever to do with our business, the two systems of illumination being totally unlike. The company referred to as the exception, is the United States Company, which owns the Maxim incandescent light, and I have never heard any one say—not even the Maxim people themselves—that our patents infringe upon theirs. The real issue between the Edison and Maxim people is that the latter's lamp is a square infringement upon Mr. Edison's."

"Had your company been threatened with prosecution for infringing patents held by the Gramme Company prior to your joining that organization?"

"No, sir. Our company has never been sued nor threatened with suit either by the Gramme Company nor by any member of the Gramme Company. Nor have we been sued or threatened with suit by any other company or inventor. We are the people to do the suing, as with reference to incandescent lighting we have exclusive ownership. In our suing processes we shall enjoy certain advantages by being members of the Gramme Company. In that company are three important committees, viz.: A Committee on Shortening and Cheapening Litigation, a Committee on Harmony, and a Committee on Prices. It is the duty of the first-named committee to simplify all litigation, and, if possible, to harmonize the differences. At any rate, all litigation between the companies in the Gramme will be tried by reference before skilled men without going into court. The Committee on Prices will see to it that each company shall sell the same quantity of goods at uniform prices."

"The Gramme Company is destined to become an absolute monopoly in electric lighting, is it not?"

"Yes," was the answer; "the company had a monopoly of arc lighting before, and now that they have got us in, they have a monopoly of incandescent lighting as well."

"How much capital is represented in the Gramme Company?"

"That is something I cannot tell you at present. I might by figuring up the value of the stock of each company interested."

"It amounts to a great many millions of dollars, does it not?" asked the reporter.

"Yes; the stock of the Edison Company alone is worth '$5,000,000.'"

The Gramme Electrical Company will probably settle upon some definite line of policy at the meeting to-day. Notice is given in their circular that "all parties manufacturing, selling, using or having in their possession electrical apparatus which infringes the patents of the Gramme Electrical Company will be prosecuted to the fullest extent of the law."

Complainant's Exhibit "Commercial Advertiser Article of August 8, 1882." S. M. H., Exr.

"Commercial Advertiser,"
Tuesday Afternoon, August 8, 1882.

AN ELECTRIC LIGHT WAR.

All the Great Companies preparing for a Campaign.

The Points in Difference Between Them.

The number of incandescent lamp systems now before the public and backed by capital appears to be four—the Edison, Maxim, Swan and Lane-Fox. In general construction and fundamental principle these lamps are practically alike—all heat to incandescence a filament of carbon in a glass globe from which the air has been exhausted. It is claimed that such a lamp was designed forty years ago, and it is said that Swan exhibited a series of such electric lights twenty years since. He admits, however, that the results then were a failure, as the filaments broke so frequently as to cause their use to be regarded as impracticable. No economic generator was at that time invented to encourage further experiments.

The external shape of these lamps is an unimportant feature, but we may state that Swan and Maxim adopt a globular form, the Lane-Fox ovoid, and the Edison is pear-shaped. The carbons in the four systems are made from different material. Thus Edison uses Japanese bamboo; Maxim, cardboard; Swan, cotton thread, and Lane-Fox, the root of Italian grass.

Maxim and Lane-Fox strengthen their carbons by heating them to incandescence in a carbonaceous vapor, thus filling interstices and perfecting the surface.

All have their special methods of fixing the carbons to the platinum conductors, which have been patented.

Such are the four great systems of incandescence now before the public, and these facts will be interesting in

view of impending complications, for the companies controlling the different systems are now actively taking steps to place their lamps upon the market, and an internecine war is about to break out among them which from the vast interests at stake and the heavy capital at the back of the combatants will probably lead to a legal contest of great magnitude. This unfortunate strife, which threatens to damage the interests of all concerned in the incandescent system of electric lighting appears to be set on foot by the "Edison Light Company" of the United States, who claim "the sole right to manufacture and sell the incandescent lamp consisting of a carbon filament in a vacum, under whatever name that lamp may be known."

It will be noticed, after this explanation, that such a claim covers the fundamental principle of the lamp. If it can be maintained in a Court of law, all other systems will have to abandon their business or pay any royalty which the Edison Company may demand.

The Maxim lamp appears to have been placed on the market both here and abroad, by the United States Electric Light Company, and has not been molested so far. Recently, however, the Swan lamp has been taken up strongly by capitalists in the United States, and will be immediately placed upon the market under the auspices and assistance of Mr. Brush, of Cleveland, Ohio, and the time has clearly come when the Edison Company must assert their claim to a monoply of the whole system of incandescent electric lighting, or quietly take their place by the side of the other companies and trade in harmony with them.

The fight will develop new features, but the contestants at present entrench themselves in following the legal positions:

The Swan, Lane-Fox and Maxim adherents claim that the fundamental principle of using an incandescent carbon in a vacum has considerable antiquity; that it cannot be patented and is the property of the whole world.

We have made inquiries of the Edison Company as to their aggressive weapons for maintaining such a valnable monopoly, and we are indebted to Major Eaton for the following thorough explanation of the Company's line of action. Major Eaton states that the fundamental patents which give Edison a monopoly of the incandescent lamp are as follows, namely: No. 238,898, dated January 27, 1880; No. 227,229, dated May 4, 1880; and No. 230,255, dated July 20, 1880. In these patents the following points are broadly covered by Mr. Edison.

1. An electric lamp having a continuous conductor (without regard to its material, resistance or mode of preparation) and an exhausted glass enclosed globe.
2. An electric lamp having a continuous carbon conductor (irrespective of its material, &c.) and an exhausted enclosed globe.
3. A filament of carbon of high resistance secured to metallic conductors(*i. e.*, the leading in wires).
4. The method of manufacture, *i. e.*, first separately forming the enclosed globe and the support for the carbon, and then affixing the carbon upon the latter, uniting the globe and support, and then exhausting.

Major Eaton follows up the above statement by this declaration which we give in his own words:

"The broad principle covered in the above-named fundamental patents allowed to Mr. Edison is so exclusive that it is not too much to say that neither Swan nor any one else has made or can make a successful incandescent lamp without infringing every one of the above patents."

Here, then, is a very pretty quarrel, the issue of which it is difficult to foresee. It has no doubt special interest for patent lawyers, who are eager for the fray. The contest has also interesting features for those capitalists who, in purchasing electric light stock, will supply the needed capital.

Complainant's Exhibit "Commercial Advertiser Article of August 10, 1882." S. M. H., Exr.

COMMERCIAL ADVERTISER.

Thursday Afternoon, August 10, 1882.

THE ELECTRIC LIGHT WAR.

EDISON'S CLAIMS PRONOUNCED ABSURD BY THE OTHER COMPANIES.

And His Plans for Lighting the Streets Said to be Defective.

A reporter of the Commercial called at the offices of the United States Electric Light Company, who own the "Maxim" incandescent lamp, to inquire what they proposed to do in regard to Edison's claim to a monopoly of incandescent electric lighting.

THE PRESIDENT: "You have the credit of publishing in specific terms what the Edison Company claim in this respect, but we, of course, knew that they proposed to make such a claim."

"What will be your reply to such a claim?"

"We repudiate it altogether, and shall continue our business as before. We desire no conflict with other companies, but if the Edison Company should take any legal steps to assert their right to such a monopoly they will find us prepared to maintain our position."

"You think Edison has no foundation for such a claim?"

"It is absurd. The fundamental principles of the present incandescent lamp were demonstrated before Edison had taken up the subject. Edison has made specific improvements, and invented methods of construction. These, if new, can be patented. We hold patents for methods of construction and devices, some of which, we believe, are being infringed on by the Edison Company, but no one owns a valid patent which would confer a monopoly of using the incandescent carbon lamp in a vacuum."

"What can be the policy of setting up such a claim if it cannot be substantiated?"

"Perhaps it may be one deeper than either of us can fathom. We, however, simply regard it as "blow," and in keeping with the record of the *great wizard's* career from first to last. If we were to analyze and explode all the claims set up at Menlo Park we should have to devote more time than could be spared for such a task."

The reporter said to the Assistant Secretary: "I noticed in the New York Tribune of Monday last that a suit had been commenced in a city out in Wisconsin between the United States Electric Light Company and the Edison Company regarding the incandescent lamp. Was that statement true?"

"The paragraph in question was a gross *canard.* There was not a word of truth in it."

"Then there are no legal proceedings between the two companies?"

"We are in conflict in the Patent Office, but not elsewhere."

"Has not the Edison Company served you with any legal notice respecting the incandescent lamp?"

"No. A printed form was sent to us from the Edison Company, which referred to an infringement; but although we are doing a large business with this lamp, we have not been restrained by any legal notice."

The New England Electric Light Company, who control the Swan electric lamp in the United States, have offices in New York. An officer of this Company said that he had read the article in the "Commercial" respecting Edison's claim to a monopoly of the incandescent lamp, but they paid little attention to it, regarding the claim as falacious. He further said that the Swan lamps were now being manufactured on a large scale and would shortly be placed on the market, to be used in conjunction with a new storage battery invented by

Mr. Brush, of Cleveland. "Every house," he continued, "using the Swan incandescent lamp will be supplied with one of these storage batteries, providing a reservoir of electricity. This, in our opinion, is the only practical manner of supplying the electric light for domestic purposes."

As the reporter was returning he met on Broadway a well-known elecritcian, who has probably done more than any other scientific man to make the electric light a practical reality. He said:

"What do you think of the possible success of lighting a large district with the incandescent lamp from a central station, as now attempted by Edison?"

"In the present state of the art of electric lighting such a thing is impossible."

"Do you, then, anticipate a failure?"

"Yes. I would personally like to see him succeed, as it would be a great advance if such a system could be established; but there are inherent difficulties which neither Edison nor any other electrician can overcome. I therefore anticipate a failure in the present attempt."

"Edison lighted up the Holburn Viaduct in London and a small district around it?"

"Yes; there is no difficulty in lighting up a large building, or externally a bridge, viaduct, or distributing the light here and there; but to say that we can light up a whole populous district in a manner to supersede gas cannot be done in the present state of our knowledge of electric lighting."

Complainant's Exhibit "Paterson Press Article of September 2, 1882." S. M. H., Exr.

"PATERSON DAILY PRESS."

Saturday, Sept. 2, 1882.

ELECTRICITY OR GAS.

THE PROBABILITY THAT THE PEOPLE OF PATERSON WILL BE ALLOWED TO CHOOSE FOR THEMSELVES BETWEEN GAS AND ELECTRICITY—THE POWERFUL COMPANY THAT PROPOSES TO WORK UNDER THE EDISON LICENSE.

Mr. John Reynolds, the president of the Paterson Gas Light Company, returned to Paterson yesterday, and this morning was found in his office by a "Press" representative. Mr. Reynolds said that the arrangements between the two Paterson gas companies and the United Gas Improvement Company had not yet been consummated, but that the only obstacle in the way was the inability of the directors of the Paterson Gas Light Company to hold a meeting. One of the principal stockholders is sick at White Sulphur Springs, Virginia, and another is at present in California. It is, however, hoped that a meeting will be held before long, so as to allow the United Gas Improvement Company to take possession on the first of October, the time first mentioned. Mr. Reynolds says that he does not know of anything else in the way of the culmination of the project. He does not think that the fact that a powerful company is at present preparing to introduce electricity into the city will have anything to do with the present project of the United Gas Improvement Company. He says that a number of the gentlemen connected with the United Gas Improvement Company are also interested in the Electric Light Company, and that the chances of the latter had been well canvassed

and examined into before any arrangement with the Paterson gas companies had been entered into.

The fact that the Electric Light Company was getting ready to go to work had been kept a secret and some of the persons interested were rather surprised at seeing the information concerning the matter in last night's "Press." The company is by no means a new one, but its operation could not be begun until the success of certain experiments in New York had been assured. The company was formed last winter and it was incorporated under the laws of this State, the certificate of incorporation having been filed with the County Clerk of Hudson County. The principal Paterson stockholders are Hon. G. A. Hobart and Mr. James Bell. Mr. Bird W. Spencer, of Passaic, is the president of the company and ex-Governor Joseph D. Bedle is also largely interested. The company obtained a license of the Edison system, which Mr. Edison was perfecting at the time, and the agreement with Edison was that as soon as his system proved a perfect success the company was to work up the cities in Northern New Jersey, Jersey City, Hoboken, Newark, Paterson, Passaic, Rutherford and other places; should the Edison system not prove a success the company would be under no obligations to him or anybody else and could dissolve as soon as it saw fit. The tests recently made by Edison seem to establish the success of his system, and on Tuesday or Wednesday one district of New York—bounded by Spruce, Wall and Nassau streets and the East River—is to be illuminated by sixteen thousand lights. Of these sixteen thousand two hundred have already been in operation for some time, and it is claimed are a perfect success. The work of the corporation which is to supply Paterson with lights was begun as soon as the practical success of the system was established, and it is claimed that a large number of agreements with mill owners have been entered into. Quite a number of private residences will also be illuminated, and it is calculated that the business in Paterson will start with at least ten thousand lights to begin with. The light will be supplied in such a way that it may be burned either very brilliantly or very low, and the cost of consumption will be in accordance with the amount of light used. The light is measured by candle light and the cost of one thousand candle light will be one dollar. Of course each burner will be equal to a large number of candle lights, but it will burn a long time before what is known as one candle light has been exhausted. The cost, it is thought, will at first be somewhat in excess of gas for residences and small establishments, but it is expected that when the concern once gets started the prices will be considerably lowered.

Yesterday's issue of the "Review of the Telegraph and Telephone," contains some interesting information concerning the progress of the work in New York. The district in which Edison is to try the electric light on a large scale is known as the lower district, New York being divided up into several districts, just as New Jersey and other States are divided into several districts. The lower district is operated by a company similar to that which is to supply Paterson with electric light. In relation to the work in the lower district the "Review" says:

Everything is now finished except putting in the fixtures which support the lamps. Bergmann & Co. are furnishing these brackets and electrollers, as the Edison chandeliers are called, at the rate of 100 a day, and 1900 are in. When 1100 more are in place, the current will be turned on. Edison has made frequent tests, having 1000 lamps lighted every day in the Pearl street station, and finds no defect. The street mains have been connected with the wires of 270 buildings. At a meeting of the company held last week, Edison was asked whether any obstacle now remained to lighting up the down-town district, and replied that he knew of none, but that, not having solved all of nature's secrets, he could not tell what would happen. His tests made down town were satisfactory.

The "New York Herald" of this morning adds that all the lamps are in, that two thousand of the lamps have been satisfactorily tested, and that all subscribers

are now waiting for is the turning on of the current. The only cause of delays now lies in the procurement of certificates from the Board of Underwriters, which are obtained through the Lighting Company and furnished to its subscribers.

The "Review of the Telegraph and Telephone," in further speaking of the work in the lower district of New York, says:

The tests undertaken by Mr. Edison upon the completion of the street work and station in his first downtown electric district, bounded by Spruce and Wall streets, Nassau street and East River, have been finished to the entire satisfaction of the experts employed by the company, who find the result better than was hoped for. The dynamos in the station at Pearl and Fulton streets have been working this week, and everything is in readiness to sell light as soon as the lamps are in the houses. An unexpected delay occurred in getting the brackets, which were to have been furnished before this. Bergmann & Co., the manufacturers of these fixtures, began delivering them yesterday at the rate of one hundred a day, and they are at once placed in position. As soon as 3,000 are in place the current will be turned on from the central station. Major Eaton, of the Edison Company, will fix no day for this event, but expects to "light up" by the 20th of September, at the latest. A gang of men is still employed making connections between the street mains and the house wires. The greatest use of the electric light in any one building downtown will be in the Mills Building, at Broad street and Exchange place, which has been "wired" for 5,500 lights. The work was done at Mr. Mills' expense by the Edison Company's men.

In answer to the many reports of failure, of unforseen obstacles, of work done for stock-jobbing purposes, Major Eaton requested a reporter of the "Evening Post," who called upon him yesterday, to say that these reports are false in every particular. The company is working as hard and as fast as it can to furnish New York with a practical and economical electric light, and is spending a vast deal of money. So far the results are perfectly satisfactory to the managers.

With regard to the rumors of important patent suits between the different companies making incandescent electric lamps, the Edison Company claims a monopoly of the business upon the following grounds: That it has patents covering (1) a continuous conductor, the light-giving filament forming part of the circuit; (2) a filament of carbon; (3) high resistance—something never before obtained; (4) "metallic leading-in" wires, ending in a clamp-like connection with the carbon; and (5) a process of manufacturing indispensable to the production of all and any of the incandescent lamps now in the market. When the Swan light, which the Brush Company is preparing to put upon the American market, is offered for sale, the Edison Company will begin suit for infringement, and also against the United States Electric Light Company should the Maxim lamp interfere with the business of the Edison Company.

As will be seen from these articles there is every probability of the success of the Edison system in New York, and as soon as the lower district has been lighted up work will be commenced in Paterson. This, of course, will be good news for Paterson. Hitherto the smaller mills have not been able to introduce the electric light on account of its cost, but now it appears as if every place in any size in Paterson may be lighted by electricity.

The Edison electric light seems to be far ahead of all other electric lights, and thousands of new lamps are being ordered every week from all parts of the United States. The last issue of "The Review" records a large number of orders received from the manufacturing establishments of the East and also some from Georgia. Its use is becoming more general every day in New York City, where many of the hotels are now illuminated with this white and brilliant light. It has also been introduced into the headquarters of the Western Union Telegraph Company. This place was dreaded by all operators and persons at all troubled with lung diseases could not stand it any length of time. The

impurity of the air was supposed to have been caused by the jets of gas used, and that this supposition was the correct one is evidenced by the fact that since the introduction of the electric light there has been no complaint concerning the condition of the atmosphere.

Complainant's Exhibit "Davenport Gazette Article of May 22, 1883." S. M. H. Exr.

"THE DAILY GAZETTE."

Davenport, Ia., May 22, 1883.

EDISON'S SYSTEM.

IT MAKES THE ELECTRIC LIGHT EVERYWHERE POSSIBLE. FACTS AND EXPLANATIONS FROM AN EXPERT.

Last week Mr. George H. Bliss, Superintendent of the Western Edison Light Company, was a visitor to this city as a guest of Mr. William Renwick. The company of which he is a member and an officer has a capital of $500,000, the shareholders in which embrace nearly forty of the foremost capitalists and business men of Chicago—Gen. Anson Stager, John B. Drake, J. W. Doane, Marshall Field, George Pullman, Edson Keith, A. F. Seeberger, John M. Clark, S. A. Clark and D. H. Louderback being among them—who have also associated with them the sagacious and reliable ex-Governor S. Merrill, of Des Moines. The sphere of this strong organization embraces the States of Illinois, Wisconsin, Iowa and Minnesota, wherein it controls all the franchise of the Edison electric light secured under the patents issued to Thomas A. Edison, the great inventor, and also under all patents yet to be issued to him, and the inventions to be made by him up to January 1, 1886. These franchises and rights are acquired under the Edison Company of New York, which own all of the Edison patents now issued, together with all to be issued and the inventions yet to be made up to January 1, 1886. That company represents a capital of $5,000,000, of which fully $2,000,000 have already been expended in the perfecting and extension of the Edison light in the United States, Great Britain, France, Germany and other parts of Europe, all the franchises of the Edison system in those countries being controlled by that organization.

Mr. Bliss is an electrician of fifteen years' continuous and active experience in connection with the development of telegraph, the telephone and the electric light. In each of these several departments of electricity Mr. Bliss has been an intelligent student as well as an industrious operator. For many months he was directly associated with Mr. Edison at Menlo Park, studying the system of electric lighting invented and perfected by that wonderful man, and making himself thoroughly familiar therewith as a worker of the inventor long before the Edison light was fully presented to the public for its acceptance and use.

Impressed with the conviction that from a scientific student and working operator in the realm of electrical discoveries and appliances information might be gleaned which would be interesting to the public, the "Gazette" assigned one of its editorial staff to the duty of interviewing that gentleman, with results thus reported:

"GAZETTE" INTERVIEWER: Mr. Bliss, so much interest has been excited in this vicinity concerning the Edison light, in consequence of its successful introduction into Iowa by the Gazette Company, that certain questions have arisen upon which you, as we believe, can give desirable information.

MR. BLISS: Well, I am certainly willing to answer any such questions, so far as within my knowledge.

"GAZETTE" INTERVIEWER: What, then, do you consider as the distinguishing excellence of the Edison light, as compared with that produced under other systems?

MR. B.: Its perfect division, subdivision and distribution. It was to secure perfection in these directions that Mr. Edison kept his system back so long from public use. You will remember how he was for two years made the butt of every scribbler's jokes while at work at this. Meanwhile the Brush and other systems were worked into use. The capitalists in New York who were furnishing the poor inventor with money became uneasy. They saw enough of Edison's light to satisfy them that it was sure to take the field. They begged him to let them introduce it to the public, so that other and inferior systems might not get a start. He was inexorable. It was his determination that every needed generator, conducting wire, switch cut-off and lamp, no matter where to be used, or whether supplied by overhead connections or underground, should be completed and tested before a single light should be placed in position outside of Menlo Park. The result has proven his wonderful prescience to have been well exercised. Not a solitary failure of the Edison light has, in consequence, been anywhere recorded. On the other hand, not one of the other systems have escaped numberless failures, and that in many and important directions.

G. I.: What are the distinguishing differences of those different systems?

Mr. B.: There are two systems of electric lighting, namely, the Arc and the Incandescent. The arc is a light of great intensity, concentrated in one small spot, constantly changing in color, and very trying to the eyes. It is now used in streets and public buildings. The Incandescent is a small, soft, steady light, of the brightness of an ordinary gas-jet of the best quality, and is especially adapted for domestic and industrial purposes. These two systems of lighting are radically distinct, a fact which must be borne in mind when comparing the Edison Incandescent system with the Arc lights.

G. I.: On what ground is the Edison system claimed to be superior to others?

Mr. B.: It is purely an incandescent light. It is created by a uniformily maintained current of electricity at what may be termed low pressure. The current emits a beautiful, soft, white light, absolutely steady and constant, and equaling in intensity, or exceeding, if desired, the illuminating power of a gas jet of the best quality. The Edison Light gives out very little heat—less than one-fifteenth as much as gas. It is absolutely free from all odor. It in no respect vitiates the atmoshere. It is positively safe from all possibility of explosion or fire. It is not anywhere injurious to the eyes; indeed, it has

been found in practice that persons whose eyes have become weak under the use of gas grow strong under the use of the Edison light. Besides, the Edison light can be conveyed into any building, factory, store, room or place, and placed in almost any conceivable position. The cheapest appliance, or the most elegant, ornate and costly, can be alike employed in the use of the Edison light illumination.

G. I.: You speak of the safety of the Edison light, do you claim that in that it is superior to the Arc Lights?

Mr. B.: Most assuredly; for the arc light is always dangerous. Mr. Edison fitly calls the arc light current "the death current," and no one who is familiar with the number of deaths which have resulted from contact with its wires and machinery will dispute the correctness of that designation. That "death current" may at any moment become destructive through the crossing of the arc light wires with telegraph and telephone wires. Property and life have frequently been destroyed in consequence. One instance occurred at Jackson, Mich., only recently, in which the apparatus of the Telephone Company's general office was destroyed through the crossing of an arc light wire with the telephone wire.

G. I.: But, in the Edison system, is there no danger of such accidents?

Mr. B.: Never. Such are impossible to the Edison system; for the very basis on which Mr. Edison has built up his lighting system was a current of electricity so mild that it could not possibly injure man, woman, boy or child. As a matter of fact, too, it never has injured any such, although thousands have used the light and have come in contact with the Edison system.

G. I.: Yes, that is so; for I have placed my own hand directly on the wire and burner of the "Gazette" dynamo itself and without receiving the slightest shock or even tremor. But how about the illumination of the arc light?

Mr. B.: The adaptability of the arc light for outdoor illumination can be judged for the experience gained in Rock Island, but need not be by me considered. In indoor illumination the arc is disagreeable, because it is too intense, flickers badly, distributes itself unevenly, casts deep shadows, and imparts a deathly palor to the countenance. It is a "death current" there.

G. I.: But it is claimed here that the Weston arc light is better and more safe than others of its class. How is that?

Mr. B.: The claim of safety is based on the allegation that the current of electricity is milder than in other Arc lights, but the conditions are not such, nevertheless, as to make it safe. It is not so. The more its lights should be multiplied the more its danger would be increased. Every person using a telephone would have reason to fear that danger.

G. I.: Well, there's the Maxim light, that also has been talked of hereabouts. What as to that?

Mr. B.: It is hardly wise for me to say or even to indicate all I know about the Maxim. I will say, however, that practically it is a dead failure. In not a single instance has it been placed in use in this country on its merits, and at a charge to the user of the full cost of its apparatus. But, beyond all, so far as we are concerned, the Maxim is an infringement on the Edison light. Some months ago the Edison people commenced suits against the Maxim folks in France. For many weeks the papers and evidence have been preparing for similar suits in the United States, and these have just now been entered. So we are not in the least concerned about the pretended opposition of the Maxim light.

G. I.: The Maxim is in use in Chicago, is it not?

Mr. B.: In a single building, the First National Bank, which has also been using the Weston light. These are both to be at once taken out as condemned. The bank has contracted with the Western Edison Light Company to light their entire edifice with the Edison light, after long and careful examinations and tests.

G. I.: Is this substitution of the Edison light for other electric light singular?

Mr. B.: Not at all; very many of such instances could be related. One establishment after another in the East has gone through that experience; for inferior systems were forced into use before Mr. Edison was ready for operation.

G. I.: How long ago was that?

Mr. B.: Only a little more than one year. Yet in New York now the second district of one mile square is being lit up by the Edison system, while a number of such establishments as that of the "New York Herald," "New York Times," Thurber's wholesale grocery house, American Bank Note Company, Hinde, Ketchum & Co.'s printing house and scores of others have adopted the light in rapid succession.

G. I.: How about the Western Union Telegraph Company's building?

Mr. B.: Well, the Western Union have in their employ some of the best electricians in the country. Those gave to the subject of electric lighting a very searching and protracted investigation. They were slow to decide and approve. At last they recommended the Edison light, and the entire W. U. establishment in New York is now being provided with that light exclusively.

G. I.: In what American manufacturing establishment is the Edison light used?

Mr. B.: To answer that would compel an enumeration which would occupy much more than one of the most closely printed columns of the "Gazette," in its smallest type, for such establishments are now to be numbered by the hundred. They include some of the largest silk, woolen, cotton and iron manufactories in New England, the Middle States and the West. The managers of those concerns are shrewd business men and proverbially cautious. They have adopted the Edison light because it is the best, the safest and the cheapest. Not a single one of these, either, has failed to approve the light and commend it to others. Those hard facts tell the whole story.

G. I.: About a "central lighting system," Mr. Bliss, what is that?

Mr. B.: Simply an arrangement under which engines and dynamos are placed in a conveniently central location in any given city and town, from which currents of electricity are conveyed by wires to the premises of such consumers as may desire to use the light.

G. I.: Is such a system applicable to Davenport, to Rock Island, to Moline?

Mr. B.: Undoubtedly. The "Gazette" plant illustrates that point. From the "Gazette" dynamo the light is conveyed in two different directions, north to the north end of Third street, and south to Second street. Did the "Gazette" plant have sufficient capacity to furnish the required current, it could as readily supply Brady street or even Main street with light.

G. I.: But, it is proposed instead, that "gas engines" be introduced and consumers use another light than the Edison? How about that?

Mr. B.: All that is a good thing to talk about but it is utterly impracticable. To carry out that plan every consumer must have a "gas engine." Besides the expense of this, there would be all the trouble of running the engine, dangers of explosions from gas leakage and the accompanying dangers of fire. Whereas, when furnished with the Edison light from a "central lighting station," the consumer will have nothing to do but turn his burner key when he wants light, no engine to look after, no engineer to employ, not even a match wanted about his premises. Besides, no American gas engine has yet been made which will satisfactorily generate an electric light. In England such an engine has been constructed, and it does very fairly. In the United States such engines have proven total failures in producing an incandescent electric light.

G. I.: What do you think, then, of that proclamation of intent by the Davenport Gas Company to furnish an electric light?

Mr. B.: What can I think but that all that had origin because of the known fact that a number of Davenport gentlemen have been seriously considering the advisability of organizing a joint stock company for the purpose of establishing a central lighting station from

which to supply the Edison light to consumers? Now, a house divided against itself is always in peril, and whenever a gas corporation attempts to hold itself between gas and electric lights there is a decidedly strong probability of a disastrous fall; by which, however, the general public may be greatly benefited.

G. I.: Then, you don't think that the Gas Company can manufacture an electric light?

Mr. B.: Certainly they can, if they can get control of an electric light for this territory, which is worth having and which is not an infringement upon the Edison Light, as the Maxim and Weston each are, certainly. But the Gas Company could even then do no more to manufacture an electric light than could any other corporation having an equal amount of capital. The gas plant would be valueless for electric lighting. Not a dollar's worth of that would be of any use, beyond possibly, the ground upon which to place engines and dynamos.

G. I.: But, the plan is to use the gas to generate electricity.

Mr. B.: That *is* a queer proposition. It is difficult to understand how coal is to be brought from Pittsburg at a cost of $5 per ton, made into gas, and the gas used to generate electricity cheaper than similar work of furnishing motive power can be done with coal costing $3 per ton. But if that can be done, then I venture the opinion that the Edison Company, of Davenport, will become the Gas Company's best customer.

There the "Gazette" interviewer came to a pause and Mr. Bliss hastened off to the evening train for Chicago, having only a few minutes to spare to reach the Chicago, Rock Island and Pacific depot.

Complainant's Exhibit, "Borden Announcement of November, 1883." S. M. H., Exr.

EDISON COMPANY FOR ISOLATED LIGHTING.

NEW ENGLAND DEPARTMENT.

HERALD BUILDING,
BOSTON, November, 1883.

DEAR SIR—Our attention having been called to a very remarkable document circulated by the New England Weston Electric Light Co., a part of which is also reprinted by the Rhode Island Electric Light Co., we feel it essential that it should not be allowed to pass unchallenged, since "truth is stranger than fiction."

Reference is made to a paper sent from the office of the President of the Edison Company for Isolated Lighting to the agents of that Company, informing them as to the apparent business of a company who sought recognition as a competitor.

The manner in which this paper came to be compiled was as follows: Many of those interested in the Edison Company were urging its officers to deal summarily with parties who were pirates of Mr. Edison's inventions—the Weston-Maxim combination being the most flagrant offenders in that direction, the only valuable parts of their incomplete system being unblushing imitations of Mr. Edison's devices. Before entering suit against these people, the president of the Edison Company sent a circular to his agents, asking for information, so that it might be ascertained if the losses by business going to the Weston-Maxim combination were of sufficient importance to justify the necessary expenses involved in suing them. The answers of the agents were compiled, and a copy of the accumulated information sent to each agent when the answers were complete.

This paper contained all information attainable to July 6, and was headed: "If any of our agents discover any errors or imperfections in this statement, they are particularly requested to communicate the same to this office."

The result of that careful inquiry was as follows: It was ascertained that in the City of New York there had been made 23 Maxim installations, of which 8, including 634 lights, a large number of which were run free, and 2 having unknown number of lamps (10 in all) were still running at the time of the inquiry. Ten others, 7 having 246 lamps, and 3 an unknown number, had been thrown out altogether, and 3 plants rejected and the Edison put in their places. *In New York City 13 out of 23 plants had been rejected because they were unsatisfactory.*

Outside of New York were found 21 of their installations (including that of Grant Bros.), permanent or on trial, of which 5 were in mills controlled and run by parties interested in the Maxim light pecuniarily, and these 5 included more than half of all the lights they had in use in the world, outside of New York. As against these seemingly permanent installations we found 9 that had been thrown out because unsatisfactory, some of them replaced by the Edison system.

To recapitulate: There were found 30 plants apparently still alive, and 22 rejected after trial. This, it must be remembered, was from the best information obtainable, and it was not obtained for public use, but for our own enlightenment.

In view of the fact that the Edison Company had 394 plants running, using over 80,000 lights (of which 274 plants, 60,725 lights, are within the United States), and no plant had ever been taken out from any buyer's dissatisfaction therewith, it seemed hardly worth while to spend the time and money involved (beyond serving a formal notice of infringement, which was done) to conduct legal proceedings for the purpose of stopping these parties from prosecuting their business, annoying as it might be for us to let them run. "The game was not worth the candle;" and from the large proportion of plants they had rejected, it seemed probable that, if let alone, they would stop without interference here as they had abroad.

This explanation seems necessary, from the attention drawn to this private paper of the Edison Company, quoted in the aforesaid circular of the New England Weston Co. It was not prepared for public circulation, but for private information. We are ready, nevertheless, to furnish the information it contains, brought from July 6th down to date, and showing an increased number of Maxim break-downs and rejections, to any party investigating the subject, for whom the affairs of the people seeking to introduce the Maxim light has sufficient interest to lead him to ask us for a copy of the paper.

In this connection we beg to state we have no controversy with Messrs. Grant Bros., who have merely allowed themselves to be used for advertising purposes by the vendors of the Maxim apparatus.

That the test of the apparatus at their mill is utterly worthless becomes apparent when attention is called to the fact that no photometric test accompanied the indication of horse-power. The writer of the present communication states, from personal observation, that the lamps at Grant Bros.' mill do not average 12-candles power of average illumination, nor do the Maxim lamps at the station of the Rhode Island Company in Providence, nor those on the Jersey City ferry boats, nor did those at the New England Manufacturers' and Mechanics' Institute at Boston.

The United States, Weston, or Rhode Island Company never installed a plant of Maxim lamps that would run 7 to the horse-power, the lamps having an average circular illumination of 16-candles power and a life of 600 hours.

When the public are informed that the relative life of incandescent lamps is in the *inverse ratio of the 4th power* of their incandesence, the "business methods" of those who would obtain and publish a statement from gentlemen, who, however skilled and successful as manufacturers, are unable to know whether lamps are at the candle-power claimed, when a test is made, can be appreciated.

A plant of 119 Edison lamps has been run over 5,400

hours at the Bay State Sugar Refinery, Boston, and broken but 74 lamps, making the average life of the lamps over 8,000 hours. We should, however, consider it both dishonest and stupid to publish that case as a sample of our system, for we know the lamps are run at not above 12-candles power for 16-candle lamps.

We feel humiliated to be compelled to pay any attention to the desperate efforts of those who seek an advertisement, by drawing us into a controversy, which their system can never give them. Our only word to our friends is, that we will not permit ourselves to continue it.

The public, who pay for electric lights, have decided who have the better system by the choice they have made in disbursing their money. This public verdict has been justified by every expert test made, from that of the Paris Exposition of 1881 to the Cincinnati Exposition of September, 1883.

With statements from a few of the users of our light, some of whom had tried and thrown out that which is deemed successful at Olneyville, and with a side-light on the "business methods" of the vendors of the Maxim lights, as shown by their action at Cincinnati, gained from a letter of Prof. Mendenhall, published in the "Boston Advertiser" of October 19, 1883, we leave this case, again offering an apology to you for a tax upon your patience in following this disagreeable duty presented to us.

THE EDISON COMPANY FOR ISOLATED LIGHTING.
SPENCER BORDEN,
Manager of the New England Department.

Complainant's Exhibit "Extracts from Edison Bulletins." S. M. H., Ex'r.

FIFTH BULLETIN.

THE EDISON ELECTRIC LIGHT COMPANY,
65 Fifth Avenue.

NEW YORK, March 17th, 1882.

MR. EDISON'S AWARDS AT PARIS. The company has obtained officially a statement of the awards made to Mr. Edison at Paris by the recent "International Congress of Electricians." The Congress subdivided its work among juries, to each of whom certain special subjects were assigned. The highest possible award the Congress could give was a diploma of honor, that being higher than a gold medal. The final award to Mr. Edison, made by the several juries, was three diplomas of honor, two gold medals and a silver medal. Pursuant to usage, however, the Congress reserved the right to reorganize awards, so as to give to each exhibitor the highest award which he had received in any one class, and the Congress therefore approved the recommendations of the juries, and itself awarded a diploma of honor to Mr. Edison. Altogether there were only eleven of the highest possible awards (the diploma of honor) granted by the full Congress, and of these only two were given to Americans, namely, one to Mr. Edison and the other on account of the telephone. The only diploma of honor awarded for an incandescent electric light was awarded to Mr. Edison. In addition to the foregoing awards, Mr. Edison received from the French Government the decoration of Officer of the Legion of Honor. He had been previously made Chevalier of the Legion of Honor, but the higher rank of Officer was conferred on account of his exhibit at the Paris Exposition.

NINTH BULLETIN.

THE EDISON ELECTRIC LIGHT COMPANY,
65 Fifth Avenue.

NEW YORK, May 15th, 1882.

THE GRAMME COMPANY. WHY WE JOINED IT. The newspaper comments about our joining the Gramme Company are misleading. The inference from them is that there has been a sort of "amalgamation" of interests, whereby the Edison Company has surrendered its autonomy and merged itself in another organization. Nothing could be more erroneous. The Gramme Company is simply a union of certain electrical companies for mutual convenience in transacting business and for protecting both the public and themselves against incompetent and in many cases swindling outside companies. The companies belonging to the Gramme association maintain their individuality intact, just as if no such union existed. There is no pooling of earnings, no parcelling out of territory, no surrender of patents, no system of mutual licensing, and no abridgement whatever of the right and power to sue each other and to sue outsiders.

The Gramme patent (U. S. patent No. 120,057, granted October 17th, 1871) is for an improved dynamo, or, as the patent reads, for "an improvement in magneto-electric machines." In May, 1879, that patent was offered for sale to our company. After taking the advice of Mr. Edison and our counsel in patent matters, we decided not to buy it. Among other reasons for our refusal was the fact that although most other inventors used the Gramme patent and made a machine more or less like the Gramme, Mr. Edison's machine was made upon an entirely different principle, and did not infringe the Gramme patent. After our company refused to buy, the patent was sold to another company. Early last year that company thought that inasmuch as most of the dynamo machines, aside from Edison's, infringed the Gramme patent, a union of the leading light companies might be formed to purchase

[NOT FILMED: PAGES 4435-4468 (EXTRACTS FROM BULLETINS ELEVEN - TWENTY-TWO)]

Complainants Exhibit
"Edison Lamp Package Label"
O.M.H. Exr

EDISON LAMP COMPANY,

SOLE LICENSEE
FOR THE MANUFACTURE OF

EDISON LAMPS

Under the following United States Patents.

		Patent No.			Patent No.			Patent No.
August	29, 1876.	181,613	October	18, 1881.	248,437	May	29, 1883.	278,416
April	22, 1879.	214,636	December	20, 1881.	12,631	May	29, 1883.	278,417
April	22, 1879.	214,637	December	27, 1881.	251,536	August	14, 1883.	283,270
August	5, 1879.	218,167	December	27, 1881.	251,538	October	30, 1883.	287,518
August	26, 1879.	218,866	December	27, 1881.	251,539	October	30, 1883.	287,519
September	16, 1879.	219,628	December	27, 1881.	251,540	October	30, 1883.	287,520
January	27, 1880.	223,898	December	27, 1881.	251,542	October	20, 1883.	287,522
February	10, 1880	224,329	December	27, 1881.	251,543	December	11, 1883.	289,837
May	4, 1880.	227,227	December	27, 1881.	251,544	February	12, 1884.	293,434
May	4, 1880.	227,228	December	27, 1881.	251,546	February	19, 1884.	293,879
May	4, 1880	227,229	December	27, 1881.	251,548	March	18, 1884.	295,398
July	20, 1880.	230,255	December	27, 1881.	251,549	April	29, 1884.	297,581
February	15, 1881.	237,732	December	27, 1881.	251,554	April	29, 1884.	297,585
March	15, 1881.	238,868	August	22, 1882.	263,135	May	13, 1884.	298,679
March	22, 1881.	239,148	August	22, 1882.	263,139	August	26, 1884.	304,086
March	22, 1881.	239,149	August	22, 1882.	263,141	October	21, 1884.	307,029
March	22, 1881.	239,150	August	22, 1882.	263,144	October	21, 1884.	307,031
March	22, 1881.	239,151	August	22, 1882.	263,145	November	18, 1884.	308,301
March	22, 1881.	239,153	August	22, 1882.	263,147	September	16, 1884.	305,191
March	29, 1881.	239,372	September	5, 1882.	263,878	May	12, 1885.	317,631
March	29, 1881.	239,373	September	19, 1882.	264,650	May	12, 1885.	317,632
April	5, 1881.	239,745	September	19, 1882.	264,651	May	12, 1885.	317,633
June	14, 1881.	242,896	September	19, 1882.	264,652	July	28, 1885.	323,150
June	14, 1881.	242,897	September	19, 1882.	264,653	January	26, 1886.	334,853
June	14, 1881.	242,899	September	19, 1882.	264,654	May	11, 1886.	341,644
June	14, 1881.	242,900	September	19, 1882.	264,655	May	11, 1886.	341,778
October	18, 1881.	248,416	September	19, 1882.	264,656	May	11, 1886.	341,839
October	18, 1881.	248,417	September	19, 1882.	264,657	November	2, 1886.	351,855
October	18, 1881.	248,418	September	19, 1882.	264,698	November	2, 1886.	351,856
October	18, 1881.	248,419	September	19, 1882.	264,737	December	7, 1886.	353,783
October	18, 1881.	248,423	October	3, 1882.	265,311	December	14, 1886.	354,310
October	18, 1881.	248,425	October	10, 1882.	265,777	January	18, 1887.	356,199
October	18, 1881.	248,426	October	24, 1882.	266,447	March	1, 1887.	358,599
October	18, 1881.	248,427	October	24, 1882.	266,588	March	1, 1887.	358,600
October	18, 1881.	248,428	November	28, 1882.	268,206	June	28, 1887.	365,509
October	18, 1881.	248,433	February	6, 1883.	271,613	September	20, 1887.	370,124
October	18, 1881.	248,436	March	6, 1883.	273,485	March	20, 1888.	379,770
			March	6, 1883.	273,486			
			March	20, 1883.	274,291			
			March	20, 1883.	274,293			
			March	20, 1883.	274,294			
			March	20, 1883.	274,295			
			March	20, 1883.	274,296			
			April	10, 1883.	275,612			
			April	10, 1883.	275,613			
			May	29, 1883.	13,940			
			May	29, 1883.	278,415			

HARRISON, N. J., U. S. A.

[NOT FILMED: PAGES 4469-4489 (PATENTS ENTERED AS EXHIBITS)]

Edison Exhibit No. 3 in Interference. S. M. H., Ex'r.

(Book No. 67. Pages 1 to 15, inclusive.)

RECORD OF LAMPS.

No. 142. Resistance, 150 ohms. } 1880. Jan. 2, Has burnt at least 200 hours. } 12 noon.

This lamp is hung on the two main wires over the pumps.

Jan'y 5, measured resistance; *no change.*

Hours.		
200.00.	Jan. 2.	
19.30.	3.	
9.58.	4.	
20.50.	5.	
3.47.	5.	
20.26.	6.	
12.15.	7.	
22.00.	8.	
9.00.	9.	Till 5 o'clock.
360.00. total.		

Jan. 9, 6.50.
Jan. 10, 19.15.
Jan. 11, 7.00.
Jan. 12, 11.00. Total, 404.05, up to noon.
Busted Jan. 13, 2 A. M.

No. 159. Hung on leading, over pumps.
Resist., 153 ohms. } Jan. 2, 1880,
Has burnt 200 hours. } noon.
Jan'y 5, measured resistance; *no change.*

		Hours.	
Jan.	2.	200.00.	
	3.	19.30.	
	4.	9.58.	
	5.	20.50.	
	5.	3.47.	
	6.	20.26.	
	7.	12.15.	
	8.	22.00.	
	9.	9.00.	Total time, 360.12. Jan. 9, 5 P. M.

Jan'y 8, resistance *same*.
9. 6.50.
10. 19.15.
11. 7.00.
12. 11.00. Total 404.05 up to 12 o'clock.
12. 9.30.
13. 11.00. " 424.35 " 12 "
13. 11.30.
14. 22.30.
15. 11.30. " 480.30 " 12 "

No. 189. Chandelier in top room nearest pumps.
Resist. 149. } Jan. 2, 1880, noon.
Has run 13 hours. }

Hours.
Jan. 2. 13.00.
3. 19.30.
4. 9.58,
5. 20.50.
5. 3.47.
6. 20.26.
7. 12.15.
8. 22.00.
9. 9.00. } Total time burned 173.12 at 5 o'clock P. M.
9. 6.50.
10. 19.15.
11. 7.00.
12. 11.00. } Total time burned 217.17 up to noon.
Busted at 8.40.

No. 275. Second chandelier, top room.
Resist. 142. } Jan. 2, 1880,
Has run 13 hours. } 12 noon.
Has run since 8.21, total running.
Broke by vibration in taking off, and on ¼ in above center (Edison saw this Jan. 2, 1880, 8 P. M.). Edison says not quite sure about this.

No. 255. Second chandelier, top room.
Resist. 200. } Jan. 2, 1880,
Has run 13 hours. } 12 noon.

Jan. 3, 19.30
4, 9.58
5, 20.50
5, 3.47
6, 20.26
7, 12.15
8, 22.00
9, 9.00 total time burned 173.12 at 5.00 P. M.
9, 6.50
10, 19.15
11, 7.00
12, 11.00 " " " 217.17 up to 12 o'c
12, 9.30
13, 11.00 " " " 237.47 " " "
13, 11.30
14, 22.30
15, 11.30 " " " 294.17 " " "
Busted.

223, third chandelier, top room.
Resist 140 } Jan. 2, 1880,
Burnt 13 hours } noon.
Jan. 3, 19.30
4, 9.58
5, 20.50
5, 3.47
6, 20.26
7, 12.15
8, 22.00
9, 9.00 total time burned 143.12 at 5.00 P. M.
9, 6.50
10, 19.15
11, 7.00
12, 11.00 " " 187.17 up to noon
12, 9.30
13, 11.00 " " 207.47 " " "
13, 11.30
14, 22.30
15, 11.30 " " 262.17 " " "
Busted.
Busted.

193, chandelier near organ
Resist 154 } Jan. 2, 1880,
Burnt 13 hours } noon.

Jan. 3, 19.30
4, 9.58
5, 20.50
5, 3.47

Taken out on Jan. 9, 1880 to put in street lamps replaced by 376 experiment.

162 chandelier near organ.
Resist 147 } Jan. 2, 1880,
Burnt 13 hours } noon.
Jan. 3, 19.30
4, 9.58
5, 20.50
5, 3.47

Taken out on Jan. 9, 1880 replaced by 375 experiment bent on end of tip taken to Cornishes where it burnt 102.00 total. Brought up for diver light.

167, third chandelier top room north side.
Resist 136 } Jan. 2, 1880,
Burnt 13 hours } noon.

Saw this burst at 3 P. M. Jan. 2. Inside glass broke. Total length of burning, 15 hours.

204 Flammer's bench.
Resist } Jan. 2, 1880,
Burning 13 hours } noon.

January 2, 1880, taken out by Edison and five pr. given Upton to make test for rupture.

Total burning, sixteen hours.

203, Flammer's bench.
142 Resist, } Jan. 2, 1880,
Burnt 5¼ hours. } noon.

After burning a total of 17½ hours it broke

155 Over Carman's desk, office.
Resist 126 ohms, } Jan. 2, 1880,
Burnt 50 hours. } noon.
Jan. 3, 19.30.
4, 9.58,
5, 20.50,
5, 3.47,
6, 20.26,

7, 12.15,
8, 22.00,
9, 9.00, total time burned, 160 hours up to 5.00.
9, 6.50,
10, 19.15,
11, 7.00,
12, 11.00, " " " 204.05 up to noon.
12, 9.30,
13, 11.30, " " " 224.35 " "
13, 11.30,
14, 22.30,
15, 11.30, " " " 280.05 " "

201 Over Carman's desk, office.
Resist 147 } Jan. 2, 1880,
Burnt 50 hours, } noon.
Jan. 3, 19.30,
4, 9.58,
5, 20.50,
5, 3.47,
6, 20.26,
7, 12.15,
8, 22.00,
9, 9.00, total time burned, 160 hrs up to 5 P. M.
9, 6.00,
10, 19.15,
11, 7.00,
12, 11.00, " " " 204.05 up to noon.
12, 9.30,
13, 11.00, " " " 224.30 " "
13, 11.30,
14, 23.30,
15, 11.30, " " " 280.00 " "

164, Office chandelier near door,
Resist 182 } Jan. 2, 1880,
Burnt 50 hours, } noon.
Jan. 3, 19.30,
4, 9.50,
5, 20.50,
5, 3.47,

6, 20.26,
7, 12.15,
8, 22.00,
9, 9.00, total time burned, 160 hrs up to 5. P. M.
9, 6.50,
10, 19.15,
11, 7.00,
12, 20.00, " " " 204.05 up to noon.
13, 22.30,
14, 22.30, " " " 224.05 " "
correct total,
15, 11.30, " " " 322.13 " "

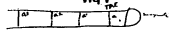
172, Chandelier over Griff's desk.
Resist 135 } Jan. 2, 1880,
Burnt 50 hours, } noon.
Jan. 3, 19.30,
4, 9.50,
5, 20.50,
5, 3.47,
6, 20.26,
7, 12.15,
8, 22.00,
9, 9.00, total time burned, 160 hrs up to 5 P. M.
9, 6.50,
10, 19.15,
11, 7.00,
12, 11.00, " " " 204.15 up to noon.
12, 11.30,
12, 22.30,
14, 11.30. " " " 259.45 " "

Electric Light

Nov 1877 2
T A Edison
Chas Batchelor
J Kruesi

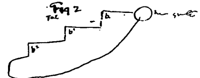
Have tried Boron Ruthenium Chromium and the almost infusible metals for separators in my Electric Light devices - Boron is very high resistance and would do if arranged thus

Fig 1



Silicium on the other hand is very low resistance and would have to be arranged thus

Fig 2



I think powdered Silicium mixed with Lime or other very infusible non Conductors or semi Conductors would be good

Copied in Vol No 1 Experimental Researches page 116 Sept 25. 1878
Wm Carman

Edison's Exhibit No 4 in Interference
[signature]

3 Electric Light Copy of this on page 116. Vol 1. Expt Researches this 20 day of Sept. 1878 [illegible] 3

Dec 3 1877
T A Edison

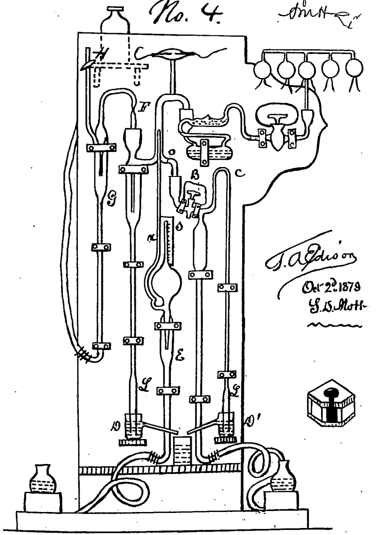
further Experiments with Rutherium & Silicon prove their adaptability to subdivision of the Light = It is possible to get good results by powdering the silicon & putting it in a glass tube passing the current through the powder

Chas Batchelor
M N Force
J Kruesi

(Edisons Exhibit No 5) [illegible]
in Interference
[illegible] Ex'r

Edison's Exhibit No. 6.
in Interference
[illegible]

No. 4.



T. A. Edison
Oct 2d 1879
S. D. Mott

Edison's Exhibit No. 7, in Interference, S. M. H., Ex'r.

Extract from records of experiments, book No. 85:

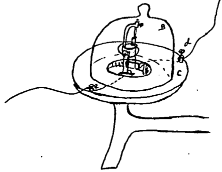
"All pumps give a great deal of trouble at F where a contraction is made so that the air in G may be forced out from H.

B. This stop cock placed too far from the main reservoir so that the tube near it caught air. This could be worked out by letting the Hg work up and down. The MacLleod should not be used until a high vacuum has been attained. For if this has not been done the Hg sticks in the side tube. Last evening a vacuum was obtained so that the spark jumped five inches outside the tube rather than across ¼ inch in vacuum. The changes in vacuum were extremely rapid from green to preventing a small spark in a few seconds and then in a few minutes to stopping the large spark. The finely divided copper and sulphuric acid may have had a strong influence on this F, the tube contracted here so that a pressure can be obtained in G to drive the air out through the stop cock H.

The enlargement of the tubes at L and L[1] is a mistake, as a bubble of air collects here and is drawn up into the pump. Making stop cock D with tube to left inclined upwards may be a mistake, as the Hg collects above the cock and stops the Geissler. Pure black rubber tube placed inside of white rubber to prevent soiling Hg.

Edison Exhibit No. 9
in Interference
J. M. H. Ex'r

A fig. 1.



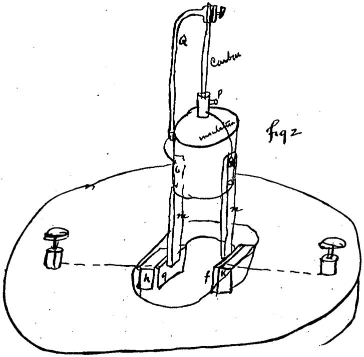


fig 2

Edison's Exhibit No. 11 (in Interference, S. M. H., Ex'r). W. H. M., Notary Public, N. Y. Co.

From Note Book No. 74, pgs. 1, 2, 5, 7, 8, 9, 10, 11, 12, 13 and 14.

RECORD OF LAMPS.

No. 159. Hung on leading wires over pumps first over pumps nearest to chandelier. Place.

Res., 153 ohms. } Jan. 2, 1880.
Has burnt 200 h. } Noon.

Jan. 2,	200.	
" 3,	19.30	
" 4,	9.58	
" 5,	20.50	
" 6,	20.26	
" 7,	12.15	
" 8,	22.00	
" 9,	15.50	Res. the same. Total h., 310.12
" 10,	19.15	
" 11,	7.00	
" 12,	20.30	Total hours burned, 381.57
" 13,	22.30	
" 14,	22.30	
" 15,	11.30	" " " 437
" 16,	23.00	
" 17,	11	" " " 471
" 17,	8	
" 18,	2	489
" 19,	8	
" 19,	11	
" 20,	11	509—over
Jan. 20, up to 509		
" 20,	11	
21,	9.15	
22,	15.45	
23,	8.00	Total, 553.10
23,	5.00	
24,	18.30	
25,	6.00	
26,	10.00	" 592.40
26,	10.40	Total, 614.20

27,	11.00	
27,	10.25	Hrs., 614.20
28,	11.00	635.40
28,	10.00	
29,	11.00	656.45
29,	11.00	
30,	16.00	
	27.00	

Busted at 8 o'clock. Total hours, 683.45

223. Third chandelier top room in laboratory.
Res., 140 } Jan. 2, 1880.
Burnt 13 hours. } Noon. Place.

Jan. 3, 32.30					
4, 9.58					
5, 23.47					
6, 20.26					
7, 12.15					
8, 22.00					
9, 15.50	Total time burned, 173.12				
10, 19.15					
11, 7.00	"	"	"	217.17	Noon
12, 20.00					
13, 22.30	"	"	"	237.47	"
14, 22.30					
15, 11.30	"	"	"	294.17	"
15, 11.00					
16, 22.00					
17, 11.00					
18, 18	"	"	"	339.17	"
18, 2					
19, 8	"	"	"	367.17	Total time

One clamp red hot; poor vacuum.
Busted at

155. Over Carman's desk, office.
Res., 126 ohms. } Jan. 2, 1880.
Burnt 50 hours. } Noon. Place 31.

Jan. 2, 50					
3, 69.58					
4, 9.50					
5, 23.47					
6, 20.26					
7, 12.15					
8, 22.00					
9, 15.50	Total time burned, 173.12				
10, 19.15					
11, 7.00	"	"	"	217.17	Noon
12, 20.00					
13, 22.30	"	"	"	237.47	"
14, 22.30					
15, 11.30	"	"	"	271.47	"
15, 11.00					
16, 22.00					
17, 19.00	"	"	"	389.17	"
18, 8.00					
18, 2.00					
19, 19.00					
20, 11.00	"	"	"	377.17	"
20, 11.00					
21, 9.15					
22, 15.45					
23, 8.00	"	"	"	416.17	"
24, 5.00					
24, 18.30					
25, 6.00					
26, 10.30	"	"	"	450.17	"
26, 10.40					
27, 11	"	"	"	471.57—over	
Jan. 27, 10.25					
28, 11.00				Total, 547	Noon
28, 10.00					
29, 11.00				Total, 538.14	
30, 12.00					
31, 11.00					

Busted at clamp or pos. 1. 562.14

201. Over Carman's desk (office).
Res., 147. } Jan. 2, 1880. Place 30.
Burnt 50 hours. } Noon.

Jan. 3, 19.30					
4, 9.58					
5, 23.47					
6, 20.26					
7, 12.15					
8, 22.00					
9, 15.50					
10, 19.15					
11, 7.00					
12, 20.00					
13, 22.30					
14, 22.30					
15, 11.30	Total hours burned,			322.13 noon.	
15, 11.00					
16, 22.00					
17, 11.00	"	"	"	372.10	"
17, 8.00					
18, 2.00					
19, 19.00					
20, 11.00	"	"	"	412.13	"
20, 11.00					
21, 9.00					
22, 15.45					
23, 8.00	"	"	"	456.13	
23, 5.00					
24, 18.30					
25, 6.00					
26, 10.30	"	"	"	496.13	"
26, 10.40					
27, 11.00	"	"	"	517.53	" over
27, 10.50					
28, 11.00				538.14 noon.	
29, 22.00					
30, 22.00					
31, 22.00					
February 1, 6.00					
2, 9.00	Total 608.14 hours.				
3, 11.00	619 "				

3, 10.00	
4, 9.00	638 hours.

Busted March 21.

164. Office chandelier, near door.
Res., 182. Jan. 2, 1880.
Noon. Place 28.
Burnt 50 hours.

Jan. 3, 19.30				
4, 9.50				
5, 20.47				
6, 20.26				
7, 10.15				
8, 22.00				
9, 15.00				
10, 19.15				
11, 7.00				
12, 20.00				
13, 22.30				
14, 22.30				
15, 11.30	Hours	burnt,	322.13,	noon.
15, 12.00				
16, 11.00	"	"	367.13,	"
17, 11.00				
17, 8.00				
18, 21.00				
19, 19.00				
20, 11.00	"	"	418.13,	"
20, 11.00				
21, 9.15				
22, 15.45				
23, 8.00				
23, 5.00				
24, 18.30				
25, 6.00				
26, 10.30				
26, 10.40	"	"	502	"
27, 11.00	"	"	523.43	
27, 10.25				
Jan. 28, 11.00	Total,	over	537.14, 5 P.	
28, 10.00				

29, 11.00 538.14
29, 11.00
30, 22.00
31, 22.00
Feb. 1, 6.00
2, 9.00
2, 9.00 " 610.14
3, 11.00
3, 10.00
4, 9.00 " 640.14, noon.

172. Chandelier over Griff's Desk.
Res., 135. } Jan. 2, 1880.
Burnt 50. }
Jan. 3, 19.30
4, 9.58
5, 23.47
6, 20.26
7, 12.15
8, 22.00
9, 15.50
10, 19.15
11, 7.00
12, 20.00
13, 22.30
14, 22.30
15, 11.30 Total hours burned, 322.13, noon.
15, 11.00
16, 22.00
17, 11.00
17, 8.00 " " " 367.13 "
18, 2.00
19, 19.00
20, 11.00 " " " 418.13 "
20, 11.00
21, 9.15
22, 15.45
23, 8.00 " " " 462.13 "
23, 5.00
24, 18.30
25, 6.00

26, 10.30 " " " 502.13 "
26, 10.40
27, 11.00 " " " 523.43
27, 10.25
Jan. 28, 11.00 " " " 544.15
28, 10.00
29, 11.00 " " " 538.15
29, 11.00
30, 22.00
31, 22.00
Feb'y 1, 6.00
2, 9.00 610.15, noon.
2, 9.00 619.15 "
3, 10.00
4, 9.00 638.15 "

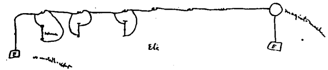
Taken to Edison's Parlor.
158.

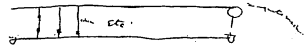
Electric Light 4th

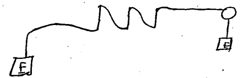
Oct 5 1877

Za Edison

Chas Batchelor







Edison's Exhibit No 13 - W.H.M. Notary public, N.Y. Co.

Mix metallic Silicum with Kaolin or Lime which will cause them to glow

in Interference

W.M.H.

317

1

July 20 1877

1 – Hammered Aluminium
2 – Platina
3 – Silver
4 – Phosphor Bronze
5 – Zinc
6 – Lead
7 – French Steel
8 – Wrought iron
9 – Nickel
10 – Russian leather
11 – White spruce shellaced
12 – Light Mahogany
13 – Box wood
14 – Brass
15 – Walnut wood
16 – Paper of all kinds
17 – Celluloid
18 – Hard Rubber
19 – Vulcanized fibre
20 – Cardboard
21 – Carbon paper
22 – Copper foil
23 – Mica
24 – Bastie Glass
25 – Papier Maché
26 – Veneering of different wood
27 – Plaster of Paris
28 – Crocodile skin
29 – Fish skin near tail (Mackerel)
30 – Paper barrel stock
31 – Iridium foil
32 – Collodionised paper
33 – Gelatin
34 – Oil board such as used for copy press
35 – Soft rubber sheets
36 – Gold foil
37 – Thin slate
38 – Oil cloth

Chas Batchelor
James Adams

(Edison's Exhibit No. 14) W. H. M. notary public. N.Y. Co.

in interference

W.H.M.

[NOT FILMED: PAGES 4510-4546 (PATENTS ENTERED AS EXHIBITS)]

that the expansion and contraction on all sides and in all parts shall be equal, in so far as there may be any tendency to throw the pencil out of its normal position laterally.

7. An electrical connection to the top and bottom end of the carbon pencil of an incandescent electric lamp, consisting of equally-divided metal electric conductors, united to the pencil at top and bottom by divided and intervening pieces of carbon, the bottom conductor being not only equally divided, but also made yielding to avoid weight, pressure, and tension upon the pencil.

8. An electrical connection to the lower end of a yielding conductor, divided equally around it, and arranged to allow it freedom of motion in the line of its axis and at the same time avoid all lateral or torsionate strain upon it.

ALBON MAN.

Witnesses:
WM. H. ALLEE,
ROBERT M. STRATTON.

Complainant's Exhibit "File Wrapper and Contents of Adams Lamp Patent," Decr. 20, 1890. S. M. H., Ex.

DEPARTMENT OF THE INTERIOR,

UNITED STATES PATENT OFFICE.

TO ALL PERSONS TO WHOM THESE PRESENTS SHALL COME, GREETING:

This is to certify that the annexed is a true copy from the files of this office of the file wrapper and contents in the matter of the Letters Patent granted Isaac Adams, Jr., July 31, 1883, Number 282,030, for Improvement in Incandescent Electric Lamp.

In testimony whereof, I, C. E. Mitchell, Commissioner of Patents, have caused the seal of the Patent Office to be affixed this 8th day of December, in the year of our Lord one thousand eight hundred and ninety, and of the Independence of the United States the one hundred and fifteenth.

[SEAL.]

C. E. MITCHELL,
Commissioner.

PETITION.

TO THE COMMISSIONER OF PATENTS:

Your petitioner, Isaac Adams, Jr., of Boston, Massachusetts, prays that Letters Patent may be granted to himself for the invention set forth in the annexed specification, and he hereby appoints Edward N. Dickerson, Jr., of the City of New York, his attorney, with full power of substitution and revocation, to prosecute this application, to make amendments and alterations therein, to sign the drawings, to receive the patent, and to transact all business in the Patent Office connected therewith.

ISAAC ADAMS, JR.

To all whom it may concern:

Be it known that I, Isaac Adams, Jr., of the City of Boston and State of Massachusetts, have invented a new and useful Incandescent Electric Lamp, of which the following is a full, true and exact description, reference being had to the accompanying drawing.

My improvement relates to an improved electric lamp designed to give light from the heating of carbon or equivalent material by the passage of the electric current, and it consists in improvements in the configuration of the bad conductor to be heated by the passage of the current, and in an improved method of setting the conductors in the glass, and an improved glass.

It is well known that one of the principal difficulties in the successful operation of incandescent lights is due to the lack of contact between the conductor and the glass through which it passes, and the consequent rupture through the point of contact and the destruction of the vacuum within the glass.

By my improvement I cause the platinum to enter the glass lamp in the shape of a tube instead of as a solid cylindrical conductor as has heretofore been done, and I find by experience that the hollow or tubular shape of the platinum causes it to yield to the expansion and contraction of the glass, and to bet-

ter accommodate itself to the varying relation between itself and the glass so as to present a more certain contact than has before been possible.

By enclosing a copper rod within the platinum tube I make the whole a better conductor than if the platinum were solid, and the conductor is likewise less expensive. When, however, I use the improved glass hereinafter described, I may use a solid platinum conductor.

It is furthermore evident that, other things being equal, the greater the surface of the incandescent carbon the greater will be the light, and, therefore, it is desirable that the carbon have as much surface as possible in proportion to the area of its cross-section.

My invention will be readily understood from the accompanying drawings in which Fig. 1 represents a view of my lamp partly in section. Fig. 2 a plan or top view. Fig. 3 represents a modified form.

A represents the glass of the electric lamp, which may be of any convenient shape; B represents conducting wires which are preferably made of copper. Surrounding each is the platinum tube C through which the conducting wire B passes. Upon this platinum tube C the cylindrical holders F are riveted. G, represents the carbon which is in the form of a flat spiral or ribbon. In the form shown in Fig. 1 the conductor C is flattened as shown at D so as to interpose as little obstruction as possible to the light from carbon G. The carbons G if made of suitable size will generally hold by their own elasticity upon the holders F but they may be wired [or clamped] thereon as shown at H or otherwise held. By the arrangement of spiral shown a very great radiant surface is obtained without the necessity of heating a large body of material. In order to properly hold the platinum tube C in the glass, such glass should be made having from 46 to 48 per cent. [of oxide of] of lead, about ten per cent. of potash [or soda or a mixture of them] and from 42 to 44 per cent. of silicate. A glass having this composition possesses about the same coefficient of expansion as platinum—is a good conductor of heat is fusible—can be readily worked, and is thereby particularly applicable to the manufacture of globes for electric lamps. This glass may be silvered on the inside by pouring a certain amount of silver solution and running it around so as to make one half of the glass a reflector.

It is preferable that the wire B and platinum C be united together only at one end. The wire [B] ~~[illegible]~~ should be preferably less in diameter than the platinum C [in order to make] ~~that is~~ make a loose fit. By this arrangement it will be found that the tube C will

May 19, '82.

yield to the varying relations between itself and the glass, and will maintain a much better contact than would be possible if it were a solid cylinder. It will also be found that for a given amount of electric current a much better result is obtained by heating the carbon spiral G than by heating a [solid] carbon cylinder.

In Fig. 3 the conductors pass out at opposite ends of the globe instead of at the same end. The arrangement is otherwise the same.

What I claim as my invention and desire to secure by Letters Patent is:

Substitute B June 16, '82.

I. A lamp which is operated by the incandescence of carbon or equivalent material produced by the passage of the electric current, provided with a tubular platinum connection passing through the glass of the lamp for the purpose of insuring a certain connection, substantially as described. A

Insert A May 19, '82.

II. A carbon for electric lamps which consists of a [spirally coiled flat carbon] ~~flat spiral~~; substantially as shown and described.

June 5, '82.

III. A glass for electric lamps which contains at the least forty per cent. of [oxide of] lead; substantially as described.

Substitute B May 19, '82.

IV. In an electric lamp the combination of a platinum tubes with the glass of the lamp; said glass containing at least forty per cent. of oxide of lead; substantially as described. (Substitute E, June 16, '82.)

V. The combination in an electric lamp of two platinum tubes passing through the glass, said tubes being provided with enlarged holders and a carbon spiral surrounding said holders; substantially as described.

VI. The combination in an incandescent lamp of a platinum conductor and glass surrounding and making contact therewith, which glass contains at least forty per cent. of lead oxide; substantially as described. (Substitute F, June 16, '82.) (June 5, '82.)

VII. The combination in an electric incandescent lamp of two platinum conductors passing through the glass, said conductors being provided with enlarged holders and a carbon spiral surrounding said holders, substantially as described.

ISAAC ADAMS, JR.

Witnesses:
GEO. H. EVANS,
WM. POLLOCK.

STATE OF NEW YORK,
City of New York,
County of New York. } ss.:

ISAAC ADAMS, Jr., the above-named petitioner, a citizen of the United States and resident of Boston, County of Suffolk and State of Massachusetts, being duly sworn, deposes and says that he verily believes himself to be the original, first and sole inventor of the improvement in incandescent electric lamp described and claimed in the foregoing specification; that the same has not been patented to himself or to others with his knowledge or consent in any foreign country; that the same has not to his knowledge been in public use or on sale in the United States for more than two years prior to this application, and he does not know and does not believe that the same was ever known or used prior to his invention thereof.

ISAAC ADAMS, JR.

Subscribed and sworn to before me this 1st day of April, 1882.

GEO. H. EVANS,
[L. S.] Notary Public (11),
N. Y. Co.

[ENDORSED:]

57,283
31

U. S. Patent Office, Apr. 4, 1882.

Room No 91.
Copied.

DEPARTMENT OF THE INTERIOR,
UNITED STATES PATENT OFFICE,
WASHINGTON, D. C., April 22d, 1882.

ISAAC ADAMS, JR.,
Care E. N. Dickerson, Jr.,
"Staats Zeitung" Blg.,
New York City:

Electric Lamps, filed April 4, 1882.
No. 57,283.

Letter "D," on 10th line from bottom of page 4, should be "B" apparently, at least it would so appear from the drawing.

Tubular leading conductors are shown in Sawyer & Man, 205,144, June 18, 1878 (Incandescent), upon reference to which the 1st claim is rejected.

The 2d claim is rejected on Edison, 223,898, Jan. 27, 1880 (Incand.), there being no invention in simply making the conductor flat.

The 3d claim is met by Nichols, 236,833, Jan. 18, 1881 (Incand.).

The 4th and 6th claims are met by the same patent, as platinum will not possess any new function over copper in this connection.

The 5th and 6th claims do not distinguish applicant's device from Edison 223,898, above cited.

KNIGHT. F. L. FREEMAN, Ex.

[ENDORSED:]

57,283
———
31

I. Adams, Jr. Rej. Apl. 22, '82.

E. N. DICKERSON, JR.,
Staats Zeitung Building,
NEW YORK, May 17, 1882.

In the matter of the application of Isaac Adams, Jr., for an improvement in electric lamps, filed April 4, 1882, No. 57,283.

Commissioner of Patents,
Washington, D. C.,

Room........

SIR:

I amend this application as follows:

Page 4, tenth line from bottom, for "D" substitute "B."

Claim 1, line 8, between "connection" and "substantially" insert "the said "tubular platinum being fused into the "glass ~~so as to insure a certain con-~~ "~~nection~~ between the glass and the plat- "inum."

Strike out the third claim, and insert in lieu thereof:

~~"A glass for electric lamps which contains from forty-six (46) to forty-eight (48) per cent. of oxide of lead, from forty-three (43) to forty-four (44) per cent. of silica, and from eight (8) to ten (10) per cent. of potash, or soda, or a mixture of them substantially as described.~~

Upon reconsideration the Office will see that the second claim is not fairly met by Edison. The claim refers to a flat spiral made of carbon alone, and not to a round spiral made of a composite of carbon, platinum and various other things. The flat spiral suggested presents substantially a rectangular cross-section, the flat spirals at the back occupying the spaces which are left open between the coils of the spiral in front, which is not true of a round spiral of the form shown by Mr. Edison; and consequently the entire space between the ends of the conductors is not in Edison's lamp utilized for the incandescent light. A flat spiral is, moreover, for many other reasons, preferable to a round carbon; as, for instance, in making connection against the holder, a very large surface can be obtained for contact between the holder and the carbon, while, with a cylindrical carbon, but a single line of contact is theoretically possible, and clamps or similar contrivances must be employed. Moreover, as compared with the radiating surface, the resistance of a cylindrical conductor or wire must necessarily be much greater proportionally than the resistance of a flat spiral or flat strip, because such strip has all or nearly all its matter utilized as a radiating surface and has no thickness in its cross-section.

The fourth claim is not met by Nicholls at all. The point of said claim is the discovery that a glass of the composition claimed possesses the same co-efficient expansion as platinum. Nicholls especially excludes platinum from his lamp and substitutes copper therefor, and attempts to make a glass or vitreous cement having the same co-efficient as copper, which is absurd; but however that may be, the composition which he makes is very different from the composition claimed by us, and it has a very different ratio of expansion from platinum instead of being identical with it as the composition claimed by Adams is.

The same remarks are applicable to the sixth claim.

As the seventh claim is allowed the fifth claim should also be, because it is more limited than the seventh.

Yrs. truly,

E. N. Dickerson, Jr.,
Atty.

[Endorsed:]

57,283 / 31 — 2

I. Adams, Jr. Amendment A, B. May 19-82.
U. S. Patent Office, May 19, 1882. Freeman, 90.

Room No. 91.
Copied.

Department of the Interior,
United States Patent Office,
Washington, D. C., June 6th, 1882.

Isaac Adams, Jr.,
Care Edward N. Dickerson, Jr.,
Staats Zeitung Blg., New York City:

Incandescent Electric Lamp,
Filed April 4, 1882, No. 57,283.

Upon re-reading the first claim as amended it will be seen that the object is twice stated.

The words "flat spiral" in the second claim is not sufficiently descriptive of applicant's carbon; it would be better to call it "a spirally coiled flat carbon."

Patent No. 223,898, cited against this second claim, is still thought to be a sufficient reference. Upon line 32 of page 2 of the patent says he has carbonized and used "papers coiled in various ways, and, as is well known, such paper carbons are always flat. It is evident that any advantages possessed by such a carbon in connection with the clamps would only support a continuation claim.

The third claim is broadly for a certain kind of glass and is not patentable except in combination with the platinum leading in conductors with which it co-operates.

In the sixth claim some limitation should be added to the word oxide, as it is evident that there are many oxides not applicable to the present invention.

Knight. Freeman, Exr.

[Endorsed:]

57,283 / 31 — 3

I. Adams, Jr. Rej. June 6, '82.

(931 F Street.)

WASHINGTON, D. C., May 29th, '83.

HON. COMMISSIONER OF PATENTS:

SIR—Please recognize Charles E. Foster and Frank L. Freeman (known as Foster & Freeman) as my associate in the matter of the application of Isaac Adams, Jr., Incandescent ^ Electric Lamp, filed Apr. 4th, '82, Serial No. 57,283, with the usual powers.

Respectfully,
E. N. DICKERSON, JR.,
Atty. for Adams.

[ENDORSED:]

Room 91.
57,283 / 3 — 4

I. Adams, Jr. Asso. Power of Atty. May 31, '83.
U. S. Patent Office. May 31, 1883.

Applicant, Isaac Adams, Jr.
Invention, Incandescent Electric Lamp.
Filed, April 4th, 1882. Serial No. 57,283.

TO THE HON. COMMISSIONER OF PATENTS:

SIR—Amend this case as follows:

1. In the amendment of May 17, 1882, erase the words "so as to insure a certain connection."

It is thought that this will relieve the claim of all objection, as the patent to Sawyer & Man is for a very different lamp, and no attempt was therein made to secure good connection between the glass globe and the leading in wires.

2. Claim 2, line 2, erase the words "flat spiral" and insert the words "spirally coiled flat carbon."

It is true that Edison suggests in his patent No.

223,898, that "he has carbonized and used cotton and linen thread, wood splints, papers coiled in various ways" and many other things, but it is evident that he never appreciated the object sought to be protected by applicant in making his carbon of a spirally ^ coiled flat carbon, as set forth in his specification. Indeed there is no evidence that Edison used a flat carbon at all, as "papers may be coiled in various ways" without being coiled flat, as claimed by applicant, and the Office cannot assume that it "might have been" so coiled.

3. Substitute for claim 3, the following:

"3. In an electric lamp and in combination with the leading in wires, a globe of glass which contains from forty-six (46) to forty-eight (48) per cent. of oxide of lead, from forty-three (43) to forty-four (44) per cent. of silica, and from eight (8) to ten (10) per cent. of potash or soda, or a mixture of them, substantially as described."

4. In claim 6, line 6, insert the word "lead" before the word "oxide."

These amendments will place the case in condition for allowance, it is thought.

Respectfully,
FOSTER & FREEMAN,
Attorneys.

June 4, 1883.

[ENDORSED:]

57,283 / 31 — 5

I. Adams, Jr. Amdt. C. June 5/83.
U. S. Patent Office. June 5, 1883.

(Copied.)

DEPARTMENT OF THE INTERIOR,
UNITED STATES PATENT OFFICE,
WASHINGTON, D. C., June 11th, 1883.

No. 57,283,
Incandescent Electric Lamp.
Filed Apr. 4, 1882.

ISAAC ADAMS, JR.,
Care Foster and Freeman,
Present :

The first clause of claim one is indefinite in phraseology, and in the amendment of the last clause the whole sentence after "so as to insure" should have been erased. Claim three is still objected to as substantially met in Nichols before cited; the cement described by appplicant is said to be used with leading-in wires, without limiting it to the use of platinum leading-in wires. Nichols does not limit himself to the exact proportions set forth of the various elements, but unites them to produce the same result in combination with leading-in wires. Claim 3 is met by Nichols, which contains *at least* 40 per cent. of oxide of lead. Claims 4 and 6 are met by the same reference, platinum tubes to permit the passing in of the conductors being old, as in Swan, 233,445, Oct. 19, '80.

In claims 5 and 7 the word "surrounding" is incorrectly used. The spiral does not surround the holders, but, as shown in the drawing, clasps the edge or is connected to it. The patents of Edison and Swan anticipate these claims. If there is any novelty in the union of the platinum tubes to the glass over that of Nichols, the difference must be clearly pointed out by disclaimer.

As presented, the claims, with the exception of claim 2, are rejected.

S. J. N. C. J. KINTNER, Ex.

[ENDORSED:]

57,283 6
31

I. Adams, Jr. Rej. June 11, '83.

Applicant, Isaac Adams, Jr.
Invention, Incandescent Electric Lamp.
Filed April 4th, 1882. Serial No. 57,283.

TO THE HON. COMMISSIONER OF PATENTS:

SIR—I amend this case as follows:

1. Substitute for claim 1 the following:

"1. In combination with the globe of an incandescent electric lamp, a tubular platinum connection passing through and sealed into the globe, whereby a certain connection between the glass and the platinum is secured."

We think the Office is in error in holding that the 3d claim is anticipated in Nichols; his composition is not only different in quantity of materials but also different in materials—he adds copper to the compound.

Moreover the objects are different; Nichols makes a cement to seal the wires to the globe, which cement is colored, as an inspection of the model will show. Applicant makes the whole globe of his peculiar glass.

We feel confident that, upon careful comparison of the two compounds, the Examiner will allow applicant's claim.

Applicant does not claim a lead glass, but only a very specific composition for such glass.

2. Substitute for claim 4 the following:

4. In an electric lamp the combination of a platinum tube with the glass of a lamp, said glass consisting of a composition of oxide of lead, silica and potash or soda combined, substantially as described.

It will be seen that the 4th claim is now limited to a composition not described in the reference, and to platinum tube; neither a tube or platinum is found in the reference.

3. Substitute for claims 5, 6 and 7 the following:

"5. The combination in an electric lamp of two platinum tubes passing through the glass globe and sealed therein, the said tubes being provided with enlarged ends or holders and a spirally coiled flat carbon, the ends of which clasp or surround the enlarged holders, substantially as described.

6. The combination in an incandescent lamp, of a hollow platinum tube passing through the glass and sealed therein, the glass being composed of a compound of oxide of lead, silica and potash or soda in substantially the proportions set forth, and a copper conductor passing through the platinum tube, substantially as described.

7. The combination in an incandescent electric lamp, of two platinum conductors passing through the glass and sealed therein, the said conductors being provided with enlarged ends and a spirally coiled flat carbon, the ends of which clasp or surround the enlarged holders, substantially as described.

8. The combination in an incandescent electric lamp, of two conductors sealed therein, one of the said conductors terminating in an enlarged end, the other being extended to near the top of the globe, bent in a reverse direction and provided with an enlarged end, and a spirally coiled flat carbon connected to the enlarged ends, the extended portion of the conductor opposite the carbon being flattened, as at D, substantially as described.

It is thought that the claims now fully distinguish applicant's lamp from the references.

Swan has platinum caps sealed to the ends of glass tubes—the glass does not surround the tubes as does applicant's.

Nichols uses conductors of copper and sets forth the advantages of that over platinum in connection with his particular glass. Applicant has clearly stated in his specification the advantages of using his particular

compound with the platinum. The objects of applicant's invention and Nichols' are different; each accomplish the object in a different manner, and it would seem that each should be protected in his invention.

June 15th, 1883.

Respectfully,

Foster & Freeman,

Attorneys.

[Endorsed:]

57,283 / 31   7

I. Adams, Jr. Amdt. D, F. June 16/83.

U. S. Patent Office, Jun. 16, 1883.

(2-024)

Serial No. 57,283.

Issue Division:
All communications should be addressed to
"The Commissioner of Patents,
Washington, D. C."

DEPARTMENT OF THE INTERIOR,
U. S. PATENT OFFICE,
WASHINGTON, D. C., July 2, 1883.

ISAAC ADAMS, JR.,
Care Foster and Freeman, Asso.,
Present:

SIR—Your application for a patent for an improvement in incandescent electric lamps, filed April 4, 1882, has been examined and allowed.

The final fee, twenty dollars, must be paid, and the Letters Patent bear date as of a day not later than six months from the time of this present notice of allowance.

If the final fee is not paid within that period the patent will be withheld, and your only relief will be by a renewal of the application, with additional fees, under the provisions of Section 4897, Revised Statutes. The office aims to deliver patents upon the day of their date, and on which their term begins to run; but to do this properly applicants will be expected to pay their final fees at least twenty days prior to the conclusion of the six months allowed them by law. The printing, photo-lithographing and engrossing of the several patent parts, preparatory to final signing and sealing, will consume the intervening time, and such work will not be done until after payment of the necessary fees.

When you send the final fee you will also send, distinctly and plainly written, the name of the inventor and title of invention as above given, date of allowance (which is the date of this circular), date of filing, and, if assigned, the names of the assignees.

If you desire to have the patent issue to assignees, an assignment containing a request to that effect, together with the fee for recording the same, must be filed in this office on or before the date of payment of final fee.

Additional copies of specifications and drawings will be charged for at the following rates: Single copies, uncertified, 25 cents; twenty copies or more, 10 cents each. The money should accompany the order.

Very respectfully,

E. M. MARBLE,
Commissioner of Patents.

Printed diagonally across the face in red ink: ☞ In remitting the final fee give the serial number at the head of this notice.

Printed on the margin in red ink: The within title is that given by the Examiner in charge as most appropriate to your invention. Should you desire a change in the same, satisfactory reasons MUST be given therefor on or before the payment of the final fee.

MEMORANDUM OF FEE PAID AT U. S. PATENT OFFICE.

Serial No. 57,283, 188 .
Inventor: Isaac Adams.
Patent to be issued to--------------------------
Name of invention, as allowed: Imp. Incandescent Elec. Lamps.
Date of payment: July 7, '83.
Fee: $20.
Solicitor:--------------------------------
Date of filing: April 4, '83.
Date of circular of allowance: July 2, '83.
Send patent to Foster & Freeman, 931 F street, Washington, D. C.

[ENDORSED:]

U. S. Patent Office, Jul. 7, 1883.

Serial No. 57,283 / 31 — 1882. — Ex'r. Book No........ Div. 10.

Patent No. 282,030. — Freeman.

Isaac Adams, Jr.,
Of Boston,
County of........,
State of Massachusetts.
Invention: Incandescent Electric Lamp.

Parts of application filed.
- Petition, April 4, 1882.
- Affidavit, " " "
- Specification, " " "
- Drawing 2 Sheets, April 4, 1882.
- Model not required.
- Specimen.
- First fee, cash $15, April 4, 1882.
- " Cert.

App. filed complete April 4, 1882.
Examined June 29, '83, C J. Kintzer, Ex.
2. Countersigned: J. W. Babson,
June 30, '83. For Commissioner.
Notice of allowance, July 2d, 1883.
Final fee, cash $20, July 7, 1883.
" Cert., 188 .
3. Patented July 31, 1883.
Att'y. or P. O. Address,
Edward N. Dickerson, Jr.,
Temple Court,
New York City.

Foster & Freeman,
Asso. present.

1882.

CONTENTS.

Application........papers.
1. April 22, 1882, rejected.
2. May 19, '82, Amdt. A. B.
3. June 6, 1882, rejected.
4. May 31, '83, Asso. Power of Atty.
5. June 5, '83, Amdt. C.
6. June 11, '83, rejected.
7. " 16, " Amdt. D. F.
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Electricity,
Electric Lights,
Incandescent.

TITLE:

Improvement in Incandescent Electric Lamps.

J. F. F.,
M. H.

[NOT FILMED: PAGES 4600-4939 (PATENTS ENTERED AS EXHIBITS)]

Edison Electric Light Co. v. United States Electric Lighting Co.

Volume VII

Supplemental Pleadings and Proofs

Circuit Court of the United States,

SOUTHERN DISTRICT OF NEW YORK.

IN EQUITY No. 3445.

THE EDISON ELECTRIC LIGHT COMPANY

vs.

THE UNITED STATES ELECTRIC LIGHTING COMPANY.

ON LETTERS PATENT No. 223,898.

Vol. VII.

Supplemental Pleadings and Proofs.

DUNCAN, CURTIS & PAGE,
Defendant's Solicitors.

S. A. DUNCAN,
E. WETMORE,
L. E. CURTIS,
Of Counsel.

EATON & LEWIS,
Complainant's Solicitors.

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Amendments to Pleadings.

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DEFENDANT'S EXHIBITS PRINTED.

COMPLAINANT'S EXHIBITS PRINTED.

STIPULATIONS.

Amendment of Answer.

[Filed June 28, 1890, pursuant to Order of Court of April 4, 1890.] 12001

CIRCUIT COURT OF THE UNITED STATES,

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT CO. vs. THE U. S. ELECTRIC LIGHT CO.	In Equity. No. 3445.

12002

And now comes the defendant herein, and by leave of Court first had and obtained under date of April 4, 1890, files the following amendment to its answer heretofore made to the bill of complaint exhibited against it:

By inserting at the end of paragraph 12 of the said answer (folio 182 of the copy of the answer as the same appears in the printed record) the following: 12003

"12*a*.—This defendant, further answering, "says, on information and belief, that during "the term of five years as aforesaid for "which said Canadian patent was granted to "the said Edison on the 17th day of November, 1879, other foreign patents for the "same invention were taken out, and among "others the said invention was patented in 12004 "the Kingdom of Sweden, and the said "Swedish patent expired prior to the expiration of said term of five years, and the "expiration of said Swedish patent was the "earliest at which any foreign patent for the "said invention had expired; that under "and by virtue of the Statute of Canada in "force when the said Canadian patent was "issued, it is provided that 'under any cir-"'cumstances, where a foreign patent exists,

12005 " 'the Canadian patent shall expire at the
" 'earliest date at which any foreign patent
" 'for the same invention expires,' and that
"under and by virtue of said Statute the
"said Canadian patent, although originally
"granted for the term of five years, expired
"at the same time with said Swedish patent,
"even if it had not expired by virtue of the
"non-fulfillment on the part of the Canadian
"patentee, or his assigns, of the condition
12006 "subsequent hereinbefore set forth; that by
"virtue of the premises the said Canadian
"patent had ceased to exist during its said
"original term of five years, and was incap-
"able under the law of Canada, of extension
"beyond said original term, and any attempt
"to extend the same by any officer of the
"Canadian government was null, void and of
"no effect; wherefore, this defendant avers
"and will contend that if the patent in suit
12007 "did not expire by virtue of the facts in the
"preceding paragraph hereinabove set forth,
"it expired by virtue of the facts in this
"paragraph stated, before the bill herein
"was filed, and this Court, has, therefore, no
"jurisdiction in equity over the alleged
"cause of action, and ought not to take cog-
"nizance of, or entertain this suit, since the
"complainant, if it has any lawful demand
"against the defendant, has a plain, ade-
12008 "quate and complete remedy at law."

THE UNITED STATES ELECTRIC LIGHTING CO.,
By G. W. HEBARD,
Prest.

DUNCAN, CURTIS & PAGE,
Solicitors for Defendant.

EDMUND WETMORE,
SAML. A. DUNCAN,
Of Counsel.

It is consented this 28th day of June, 1890, that

the above amendment to defendant's answer may 12009
be filed *nunc pro tunc* as of the 4th day of April,
1890.

EATON & LEWIS,
Solicitors for Complainant.

Second Amendment of Answer. 12010

[Filed March 7, 1891, *nunc pro tunc* as of October 10, 1890.]

UNITED STATES CIRCUIT COURT,

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY 12011
vs.
THE UNITED STATES ELECTRIC LIGHTING COMPANY.
} In Equity. No. 3445.

And now comes the defendant, by order of Court 12012
first had and obtained under date of December 10,
1890, and amends its answer herein by inserting, at
the end of Subdivision A of Section 7 of the same,
the following:

"ISAAC ADAMS, who now resides at Annisquan, Essex County, Massachusetts, and who invented, made and used the same at Boston, Massachusetts, and New York City; to the knowledge of Aquila Adams, who resides at Sandwich, New Hampshire, H.

12013 Julius Smith, who resides at Pompton, New Jersey, and others."

THE UNITED STATES ELEC. LIGHTING CO.,
Defendant,
By KERR & CURTIS,
Solicitors.

SAM'L A. DUNCAN,
Of Counsel.

It is stipulated this 7th day of March, 1891, that the foregoing amendment to the answer may be
12014 filed *nunc pro tunc* as of the 10th day of October, 1890, and that the replication heretofore filed by the complainant may stand *nunc pro tunc* as a replication to the answer as amended, and to the defendant's plea as heretofore amended, but subject to all rights reserved to the parties hereto as to said plea by the stipulation made between them on February 12, 1889, and printed on pages 30–1 of the printed record.

RICH'D N. DYER,
12015 Of Counsel for Compl't,
SAM'L A. DUNCAN,
Of Counsel for Def't.

12016

Amendment of Second Amended Plea. 12017

[Filed June 28, 1890, by order of Court of April 4, 1890.]

CIRCUIT COURT OF THE UNITED STATES.

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT CO. vs. THE U. S. ELECTRIC LIGHT CO.	In Equity. No. 3445.	12018

And now comes the defendant herein, and by leave of Court first had and obtained under date of April 4, 1890, makes the following amendment to
its plea—that is to say, to its second amended plea, 12019
heretofore filed to the bill of complaint exhibited against it:

Insert at the end of the last paragraph but two of said second amended plea (at the end of folio 208 of the printed record herein) the following:

"And this defendant further avers, on information and belief, that during the term of five years as aforesaid for which said
Canadian patent was granted to the said 12020
Edison on the 17th day of November, 1879, other foreign patents for the same invention were taken out, and among others the said invention was patented in the Kingdom of Sweden, and the said Swedish patent expired prior to the expiration of said term of five years, and the expiration of said Swedish patent was the earliest at which any foreign patent for the said invention had expired; that under and by

12021 "virtue of the statute of Canada in force "when the said Canadian patent was issued, "it is provided that 'under any circumstances "'where a foreign patent exists, the Canadian "'patent shall expire at the earliest date at "'which any foreign patent for the same in- "'vention expires,' and that under and by "virtue of said statute the said Canadian "patent, although originally granted for "the term of five years, expired at the same
12022 "time with said Swedish patent, even if it "had not expired by virtue of the non-ful- "fillment on the part of the Canadian paten- "tee or his assigns of the condition subse- "quent hereinbefore set forth; that by "virtue of the premises the said Canadian "patent had ceased to exist during its "original term of five years and was in- "capable under the law of Canada as afore- "said of extension beyond said original
12023 "term."

THE UNITED STATES ELECTRIC LIGHTING CO.,
By G. W. HEBARD.
Pres't.

DUNCAN, CURTIS & PAGE,
Solicitors for Deft.,

EDMUND WETMORE,
S. A. DUNCAN,
Of Counsel.

12024 It is consented this 28th day of June, 1890, that the above amendment to defendant's plea may be filed *nunc pro tunc*, as of the 4th day of April, 1890.

EATON & LEWIS,
Solicitors for Compl't.

Proceedings of March 7, 1891. 12025

CIRCUIT COURT OF THE UNITED STATES.

SOUTHERN DISTRICT OF NEW YORK.

THE EDISON ELECTRIC LIGHT COMPANY
vs.
THE UNITED STATES ELECTRIC LIGHTING COMPANY.
} In Equity, No. 3445. 12026

Proceedings before S. M. Hitchcock, the Examiner.

NEW YORK, MARCH 7, 1891.

Met by agreement of counsel at the office of Dyer & Seely, 34 Wall St., at 12.30 P. M. 12027

Present—R. N. DYER for complainant;
S. A. DUNCAN for defendant.

Counsel for defendant, in order to complete "the the judicial literature appertaining to the patent in suit," offers in evidence the following papers:

1.—A copy of the decision of Mr. Justice Kay, rendered July 16, 1888, in the Chancery Division of the High Court of Justice of England, in the suit of Edison & Swan United Electric Light Company *v.* Holland. 12028

2.—A copy of the decision of the Royal Kammergericht (Sixth Civil-Senate) of Berlin, in the Kingdom of Prussia, rendered May 5, 1890, on the appeal taken in the suit of Thomas Alva Edison *v.* Naglo Brothers, decided in the first instance by the Royal Landgericht of Berlin, II. Civil Chamber, on March 9, 1885.

12029 3.—A translation of the last-named decision.

4.—A copy of the report of Prof. Kohlrausch referred to in the last-named decision, and made a part thereof.

5.—A translation of the said report of Prof. Kohlrausch.

The said papers to be marked by the Examiner respectively as

"Defendant's Exhibit Decision of Justice
12030 Kay."

"Defendant's Exhibit Decision of the Royal Kammergericht."

"Defendant's Exhibit Report of Prof. Kohlrausch."

Complainant's counsel states that he waives any informality in connection with the offering of the above papers on the ground that defendant's time to take testimony has expired; and further that he wishes it understood that this waiver extends only
12031 to the particular papers named, and is not to be taken as admitting defendant's right to take further testimony.

Proceedings of March 14, 1891.

12032 NEW YORK, March 14, 1891.

Present.—S. A. DUNCAN, Esq.,
Of Counsel for Defendant.

S. B. EATON, Esq.,
R. N. DYER, Esq.,
Of Counsel for Complainant.

Defendant's Counsel offers in evidence a copy of a portion of the deposition of Dr. Charles F. Chandler, taken in behalf of the plaintiff in a suit

brought and now pending in the United States Cir- 12033
cuit Court for the District of New Jersey, between the Edison Electric Light Company, the plaintiff in the present suit, and Westinghouse, Church, Kerr & Co.; the portions of said deposition thus offered being as follows:

Questions and Answers Nos. 1 to 7 inclusive; 9 to 11 inclusive; 14; 43 to 46 inclusive; 94 to 99 inclusive; 106 to 121 inclusive.

Defendant's Counsel offers in evidence a copy 12034
of the Specification and Drawing of a patent of the United States granted to Thomas A. Edison, on the 19th of September, 1882, and numbered 264,642, being the patent involved in the before-mentioned suit pending in New Jersey.

Upon request the Examiner marks the aforesaid copy of testimony as "Defendant's Exhibit, Chandler's Testimony in the 'Feeder and Main' Suit."

Also Patent is marked "Defendant's Exhibit 12035
Edison's 'Feeder and Main' Patent, No. 264,642."

It is admitted by counsel for plaintiff that Dr. Charles F. Chandler was called as a witness in said suit aboved named, in behalf of the plaintiff therein; that the plaintiff in said suit is the same as the plaintiff in the present suit; and that the foregoing extracts from the deposition of Dr. Chandler in the said case are, *pro tanto*, correct copies of the
testimony actually given by him therein. 12036

Complainant's Counsel objects to the Exhibit composed of extracts from Prof. Chandler's testimony, as incompetent, immaterial and irrelevant; as not being directed to the issues in this case; and as being only a portion of the entire deposition.

Defendant's Counsel states that, inasmuch as certain other portions than those above named of the deposition of Prof. Chandler in the "Feeder and Main"

12037 case have been designated by complainant's counsel as essential portions of the context, Defendant's Counsel will print the portions thus designated in conjunction with the parts which he has already offered in evidence, and consents that they be regarded as a part of the record in the present case.

The parts of Prof. Chandler's deposition thus designated by complainant's counsel are the following:

Questions and Answers Nos. 8, 12, 13, 15,
12038 17, 34, 38, 39, 40, 41, 42; 47 to 52 inclusive; 55; 62 to 68 inclusive; 72 to 74 inclusive; 100 to 105 inclusive; 122 to 125 inclusive; 202 to 204 inclusive; 245 to 247 inclusive.

It is stipulated that the foregoing questions and answers as they appear printed with the matter introduced by the defendant, are correct copies.

(The above extracts from Prof. Chandler's Depositions are printed below on pages .)

12039

PROF. CHARLES F. CHANDLER, being produced as a witness for the complainant, and being duly sworn, deposes in answer to questions by complainant's counsel, as follows:

1 Q. Are you the same witness who has testified as an expert in the case of The Edison Electric Light Company against Westinghouse, Church,
12040 Kerr & Company, pending in the Circuit Court of the United States for the District of New Jersey, a portion of whose testimony has been introduced into this record?

A. I am.

2 Q. Referring to your answers to 9 Q, to 46 x-Q, to 96 x-Q, and to 97 x-Q, of your deposition in that case, please state whether you have had any, and if so what, experimental knowledge of the lamps mentioned in those answers or any of them, other than the carbon filament lamp of Mr. Edison?

A. With a single exception I have not had any 12041
experimental experience with any of them. That exception is in the case of a Lane-Fox platinum lamp, though I am not absolutely certain that that was the platinum lamp which was made by him prior to 1880, as it was some years after that before I obtained possession of the lamp, and it may have been a lamp of later construction.

I had three specimens of this lamp and connected them, when I obtained them, with the wires supply-
ing current from a dynamo to my lecture-room. 12042
The current was not adapted to them and destroyed them at once. I have seen a Werdermann lamp but never had an opportunity to experiment with it.

3 Q. What is the character of the Werdermann lamp?

A. The Werdermann lamp is an arc lamp with very short arc; in fact, the lower carbon makes a rough or imperfect contact with the upper carbon
—a variable contact which might be called a "mic- 12043
rophonic" contact. The result is the production of an arc. The carbon is not a continuous conductor.

4 Q. Does the brief experience you had with what you suppose were Lane-Fox platinum lamps enable you to say that such lamps were capable of practical use had they existed prior to 1880?

A. I suppose from what I have read about them that they might have been made available for use, at least to some extent, with proper means for reg-
ulating them. But my own experience gave me no 12044
basis on which to form an opinion, as they were destroyed the minute I turned on the current.

5 Q. Your knowledge as to the other early lamps referred to by you, then, was derived from the same sources?

A. Yes, it was the general impression left in my mind from what I had read. It was not based on any exact experiments that I remember anyone to have published.

12045 CROSS-EXAMINATION BY GENERAL DUNCAN:

6 x-Q. One of the earlier lamps referred to by you in your deposition was the King lamp of 1845, or thereabouts. Have you had occasion to read and consider the published accounts of the performance of that lamp—notably the account given by Matthieu Williams?

A. I do not recollect ever seeing that account.

7 x-Q. As I understand your account of your experience with the Lane-Fox platinum lamps, the
12046 burners were destroyed because the current used was not adapted to them; is that a correct understanding of the matter?

A. It is.

8 x-Q. Is it not an easy matter to destroy the carbon burner of one of the modern commercial incandescent lamps employing carbon burners by using a current not adapted to such burner?

A. It can be done, but it does not happen in such a short period of time, because the carbon is not
12047 fusible, while the platinum fuses at a temperature slightly above the proper temperature of incandescence.

9 x-Q. Still it is possible, is it not, to destroy the filamentary burner of a modern incandescent lamp in a very few minutes by using a current not adapted to the lamp?

A. Yes, I suppose it is.

10 x-Q. In point of fact, is it not regarded as necessary in the practical working of the modern
12048 lamp that uses a carbon burner, to regulate the current with special reference to the character of the particular lamp that is being supplied by such current?

A. It is.

11 x-Q. You have spoken of the Werdermann lamp as an arc lamp; is not that generally classed as an incandescent or at least "semi-incandescent" lamp?

A. It is sometimes called an incandescent-arc lamp, but Werdermann himself insists upon it in

his patent as producing a distinct arc, and lays great stress upon this point. 12049

12 x-Q. Is not the light derived more particularly from the incandescence of the carbon than from the arc which you assume to be formed?

A. No, I think not.

13 x-Q. In the Werdermann lamp, is not the light produced by the incandescence of the carbon in a much greater proportion than in what is ordinarily called the arc lamp?

A. Yes, I suppose it is, because the lower carbon 12050
in the Werdermann lamp is a smaller rod than is usually employed in large arc lamps.

Complainant's counsel offers in evidence the following questions and answers from the deposition of Sir William Thompson, taken by the complainant in the same suit in which the deposition of Prof. Chandler was taken,
to wit: 12051

Nos. 1 to 14 inclusive; 15 down to the session of January 8, 1891; 48; 99 to 160, inclusive; 246 to 260, inclusive; 264; 332, excepting next to last paragraph beginning with the words "Both in the questions" and ending with the words "without pressure wires."

It is stipulated that Sir William Thomson
testified as a witness for the complainant in 12052
the New Jersey "Feeder and Main" suit as before stated; and that the foregoing extracts are correct copies, *pro tanto*, of his deposition; Complainant's counsel offers to make, as a part of complainant's exhibit, any further questions and answers from Sir William Thomson's deposition that defendant's counsel may indicate.

Defendant's counsel objects to the introduction into this case of the testimony of Sir

12053 William Thomson, as inadmissible under any known rules of evidence, he not having been sworn as a witness in this case, and not being produced for cross-examination.

Without waiving the foregoing objection or any other legal objection that may lie against the reception of the said testimony, defendant's counsel would designate the following parts of the deposition of Sir William Thomson as parts which he desires to have
12054 printed in connection with the parts that have been offered by plaintiff's counsel, in the event that the Court shall decide to permit any portion of said deposition to be read in evidence, to wit:

x-Q. and Ans. 293., together with the objections which appear in Sir William Thomson's deposition, in connection with those parts which have been offered in evidence by complainant.

12055

It is admitted by defendant's counsel that in the suit of the Consolidated Electric Light Company against the McKeesport Light Company, pending in the Circuit Court for the Western District of Pennsylvania, and decided by Mr. Justice Bradley, October 5, 1889, whose opinion appears at page 382 of Vol. 1 of the printed record, the complainant
12056 was controlled by the Westinghouse Electric Company, of Pittsburg, and the said suit was conducted for the complainant by the counsel of the said Westinghouse Electric Company.

It is also admitted by defendant's counsel that the defendant in the present suit, The United States Electric Lighting Company, is controlled by the said Westinghouse Electric Company, and that the defence in this suit has been conducted by the counsel of said Westinghouse Electric Company.

Defendant's Exhibit Decision Mr. Justice Kay.—S. M. H., Ex. 12057

IN THE HIGH COURT OF JUSTICE—CHANCERY DIVISION.

EDISON AND SWAN UNITED ELECTRIC LIGHT COMPANY
v.
HOLLAND and others. 12058

MR. JUSTICE KAY, on Monday, July 16, 1888, delivered judgment in this action.

His Lordship said: The plaintiffs sue the defendants for infringing two Letters Patent; one Edi- 12059
son's patent, No. 4,576 of November 10th, 1879; the other Cheesbrough's patent, No. 4,874 of 1878, amended by disclaimer dated the 12th of November, 1884. Both patents relate to electric incandescent lamps. The defense is taken up by third parties, the Anglo-American Brush Electric Light Corporation. The validity of both patents is put in issue.

The first thing necessary is to ascertain, as ac- 12060
curately as is possible to any one who has not had the requisite scientific training, what was known on the subject at the date of these patents, say in 1879.

There are two commonly known systems of electric lighting, the arc and the incandescent systems. These patents relate to the latter. The

12061 former depended upon a break in the conducting material occurring at a point where the conductor was carbon in the form of a pretty thick pencil. The current leaped over the break in an arc, gradually destroying the carbons; and this arc gave a vivid white light, especially at the positive pole. The incandescent system is different. The conducting material in this is continuous, without any break or actual interval, but, being in part an imperfect conductor, that part becomes heated by its resistance
12062 to what is termed the passage of the current, and this heating, raised to an intense degree, gives the light now familiar to us in the incandescent lamp. The material which is now so heated is some form of carbon. It was well known that this was a good material for the purpose, because it was an imperfect conductor—in other words, had a high specific resistance—and that it was essential to use it in a vacuum or in some gas or vapour which did not contain oxygen, otherwise the carbon consumed
12063 quickly.

Until 1872, when Sprengel's air-pump was improved by Mr. Crookes, it was difficult to obtain a vacuum which was complete enough. The consequence was, that it was necessary to employ a pencil of carbon of comparative thickness, because there was enough oxygen left within the exhausted glass bulb to occasion some consumption of the enclosed carbon, and also enough air to diminish the bulk of the carbon when incandescent by frictional action upon
12064 its heated surface, which Edison in his specification and some of the witnesses have called "air-washing."

Another difficulty which prevented the use of very slender carbons was the irregularity of the current obtained from the dynamo. It was subject to variations, which at times produced a current stronger than the carbon could bear. This was remedied by the improvements of Gramme and Brush, which were perfected in the year 1878.

Two modes of improving the resistance of

the carbon were known, one by increasing its 12065
length, the other by the diminution of its thickness —or, to use the more exact language of the witnesses, of its sectional area. It was known that the carbon for an incandescent lamp must be enclosed in a glass bulb from which the air must be exhausted. Bulbs made entirely of glass had been used and publicly exhibited for this purpose.

It was known that molten glass could be made to adhere close to platinum wires, because the glass proper for the purpose expands with heat in the 12066
same degree as that metal; and that for this reason, and also because of its properties as a conductor of electricity, the best mode of connecting the carbon within the glass bulb with the main wires through which the current passed, was to unite each end of it to a thin platinum wire, and to fuse the glass around these wires so that air should not penetrate at the points at which they entered the bulb.

It was known that by increasing the electromotive force the main wires bringing the electric current 12067
through the lamps might be reduced in size, just—to take the illustration given by Sir F. Bramwell—as by increasing the hydraulic pressure in the pipes supplying a town with water, you are enabled to use smaller pipes, because the water will pass with accelerated velocity.

It was known that by using high resistance in the incandescent portion of the lamp smaller leading wires might be employed, and also a greater number of lamps might be illuminated from the same 12068
source of electricity by working them, as Dr. Hopkinson calls it, in multiple arc or in parallel. Two systems of using incandescent lamps were known, and it was recognized that when many lamps were to be lighted from one central station, and at some distance, the system called "multiple arc" or "in parallel" was best. That may be shortly described as a plan involving the use of one main leading and one return wire, each lamp being supplied with electric current by a smaller wire from the main

12069
leading wire, and returning such portion of the currents as it took to the return wire, the main leading wire and the return wire being supposed to be parallel. The other system, which is little employed, was the use of lamps "in series." In this case the whole current is sent through each lamp in succession, and accordingly lamps of comparatively low resistance are required.

The desideratum in 1879 was to obtain lamps of high resistance for the "multiple arc" system,
12070 which could be made "commercially," that is, in large quantities with reasonable cheapness, and above all, that it should have durability. Edison, Lane-Fox, Swan and others have been working with this object in the same direction.

On December 19, 1878, in a lecture given by Swan at Newcastle, he described an experiment on the production of light by passing a current of electricity from a dynamo through a slender rod of carbon enclosed in an exhausted globe. On January 17th, 1879, he lec-
12071 tured on the same subject at Sunderland, illustrating his lecture by experiments, exhibiting certain electric lamps. On February 4th, 1879, he again lectured at Newcastle, and he then exhibited the lamp which has been produced in evidence. It consists of a bulb made entirely of glass with leading plantinum wires sealed into it and connected with a pencil of carbon inside the bulb. This piece of carbon was obtained from Carré, of Paris, and was manufactured by him and shaped before being carbon-
12072 ized. It is 1-25 of an inch in diameter, that is considerably thicker than the carbons now used, and being straight, the leading wires are sealed into the bulb at opposite ends. This renders it liable to a defect which is alluded to in the correspondence between Swan and Mr. Stearn, viz.: Rupture of the carbon, or its separation from the wires by expansion and contraction under the great heat to which it is exposed. This lamp was exhibited again at Gateshead on the 13th of March, 1879, and seems to have been kept lighted for ten to twenty

minutes at a time on two or three occasions without 12073
injury. I have no evidence how long it would last if continuously used.

Swan, in the spring of 1879, ordered from Carré carbons in the shape of a hair pin, a model of which he produces. It is practically identical in form with some of the carbon now used in lamps, but with a larger sectional area. Lamps made with these would not have the defect to which I have alluded. He says that probably toward the end of
1879 he made some lamps with those hair pin car- 12074
bons. They are referred to by Mr. Stearn in a letter dated the 26th of November, 1879, in which Figure 2 is a sketch of a lamp, so mounted, but I do not lay much stress upon this as an anticipation of Edison, for, although Heaviside and other witnesses speak of having seen these lamps in 1879, I think the fair result of this evidence is that these were experiments which did not succeed in producing a commercially successful result before Edison's
patent. On the 2nd of January, 1880, Swan ob- 12075
tained a patent for one of the most valuable inventions connected with the manufacture of incandescent lamps. That was for preparing the carbon by passing the electric current through it and heating it to incandescence while the bulb was still connected with a Sprengel air pump in action. This is now always done, and the effect is to make the vacuum much more perfect, or rather, less liable to be impaired by air or gas coming from the carbon
itself when first heated in a vacuum. On the 21st 12076
of January, 1880, he obtained a patent for a horse-shoe strip of card board prepared for an incandescent lamp by converting it into a substance like parchment by treatment with sulphuric acid and then carbonizing. On the 27th of November, 1880, he obtained a further patent for the application of this process to cotton thread. This has proved a most valuable invention. It produces a non-structural tough material, said by one of the witnesses to be hard and stiff as a metallic wire, and

12077 this is now largely used for incandescent lamps. Mr. Edison applied to the object of producing a lamp of high resistance his untiring and apparently inexhaustible ingenuity, but his specification shows—as Sir F. Bramwell states —that he was not aware how much was actually then known to electricians like Lane-Fox and Swan, and Edison conceived that he was the first inventor of some matters in which they seem to have anticipated him. Edison
12078 availed himself of the more perfect vacuum obtained by the Sprengel pump, and also of the known principle of increasing the resistance of the carbon by diminishing its sectional area, which had become possible to a much greater degree, owing to the perfecting of the Sprengel air-pump and the dynamo.

The most important point raised upon the construction of his patent of November 10, 1879, is the
12079 extent of the second claim, whether it includes every lamp of the kind there described, the light giving carbon in which is a "filament," or whether it means only lamps with such filaments as are particularly mentioned in the body of the specification.

Another point is upon the first claim—whether the word "lamp," in that claim, does not mean merely the filament of the carbon.

A third question of construction is whether the
12080 carbonization of the filament is to be effected before or after it is attached to the platinum wires.

With respect to the sufficiency of this specification, it is urged that Edison ought to have defined exactly what was meant by the word "filament," and that his patent of 1879 is void for insufficiency of specification in this respect, and also because it does not give sufficient directions for carbonizing filaments. None of the modes of making filaments particularly described, it is said, are practical; or, at any rate, some are not, especially the several 12081
modes of making filaments from a putty composed of lamp-black and tar, and from that putty compounded or coated with various substances. Also, if the patent means that the filament is to be carbonized after being attached to the platinum wires, this, it is said, is impracticable, because the platinum wires would thereby be made porous and brittle, and could not be sealed into the glass so as to prevent air getting in at the point of sealing, or through the pores in the wire.

The proper mode of constructing a specification, 12082
as laid down by Lord Wensleydale in "Neilson *v.* Harford," is to hold a fair hand between the patentee and the public, willing to give the patentee on his part the reward of a valuable patent, but taking care to secure to the public, on the other hand, the benefit of that provision which is introduced into the patent for their advantage. This refers to the condition expressed in every patent, that the patentee shall particularly describe and ascer- 12083
tain the nature of his invention, and in what manner the same is to be performed. Lord Westbury's exposition of the rule of construction, taken from his judgment in "Simpson *v.* Holliday," in the 13th Weekly Reporter, is somewhat more explicit:

"With respect to the rules that govern the "construction of specifications," he says, "they are the ordinary rules for the interpre- "tation of written instruments, having regard 12084
"especially to the fact that the specification "must clearly fulfill the obligation imposed "upon the patentee by the proviso contained "in all Letters Patent—namely, that the grant "shall be void if the patentee shall not parti- "cularly describe the nature of his invention, "and in what manner the same has to be per- "formed.

"It is, therefore, made a settled rule that "the specification must be so expressed as to "be perfectly intelligible to a workman of "ordinary knowledge, and it must follow that, 12085 "if there is any obscurity or ambiguity in the "specification which is likely to mislead, this "defect ought not to be helped by any refined "or secondary interpretation of the language.

"It was contended before me, and the Vice-"Chancellor is reported to have said that it "has been settled by authority that the most "liberal construction is to be given to a patent "that will sustain it, especially in those cases "where the Court is satisfied that the inven-"tion is really new and useful. If the words "'most liberal construction' are intended to
12086 "denote some particular principle of inter-"pretation different from the ordinary rules "for the construction of written instruments. "I am not aware of any such authority. The "Vice-Chancellor is made to say that this "liberal construction is adopted in cases "where the Court is satisfied that the inven-"tion is really new and useful. But novelty "and utility are necessary for the validity of "every patent. There is probably some in-"accuracy in the note of the judgment."

12087 That case went to the House of Lords, and is reported in *Law Reports of the House of Lords*, page 315. None of the learned Lords in any way dissented from the passage which I have read. I take from the speech of Lord Chelmsford, then Lord Chancellor, the following passage:

"The construction of a specification, like "other written documents, is for the Court. "If the terms used require explanation, as
12088 "being terms of art or of scientific use, ex-"planatory evidence must be given, and with "its aid the Court proceeds to the office of "construction."

The particular decision in that case was that a description of a process for producing a purple color from aniline by mixing it with dry arsenic acid, and allowing the mixture to stand for some time, or accelerating the operation by heating, was void, because it could not be done without heating, and that was described as an alternative process.

With regard to the construction of Edison's patent, No. 4576, of 1879, I observe, first of all, that 12089
the provisional specification begins by stating the necessity that lamps connected in multiple should be employed without main wires of great size, and that it is essential that these lamps should have a high resistance. It is stated that this had been set forth in a previous patent of Edison's of the same year, and that lamps of great resistance had been obtained by a long wire of platinum or other metal pyro-insulated (which means coated with 12090
an incombustible substance) and coiled so that but small radiating surface was exposed. Then it is said that the present invention relates to lamps of a similar character, except that carbon threads or strips are used in place of metallic wire, and connected to platinum wires sealed into a bulb exhausted of air. A description of the mode of manufacture is then given, but not in so much detail as in the complete specification. Turning to that, I find that it commences with a short state- 12091
ment that the object of the invention is to produce incandescent lamps of high resistance. Then follow four paragraphs stating in what the invention consists. The first of these is the coiling of carbon wire or sheets so as to offer great resistance and present but a slight surface for radiation. The next the placing of such light-giving body of great resistance in a nearly perfect vacuum. The third states that the connecting wires are platinum, sealed into the glass. The fourth is the method of 12092
manufacturing carbon conductors of high resistance, and securing perfect contact between them and the wires.

The specification next states Mr. Edison's view of what had been done up to that time. It is admitted that this is inaccurate in many respects. He appears to have been unaware of the attempts that have been made to do the very thing at which he was aiming—that is, to increase the resistance of the carbon burners in lamps made of bulbs of glass

12093 exhausted of air, the connecting wires being of
platinum sealed into the glass. He seems ignorant that bulbs made entirely of glass had been used, or that they had been exhausted of air so as to form a vacum. The statement is that theretofore the air has been replaced by gases that do not combine chemically with the carbon.

The specification then proceeds to describe the several modes of making the carbon burners. I find mentioned (1) cotton thread; (2) any fibrous
12094 vegetable substance which would leave a carbon
residue after heating in a closed chamber; (3) such fibrous material rubbed with a plastic compound composed of lampblack and tar; (4) carbon filaments made by a combination of tar and lampblack; (5) sometimes a thread rolled in such compound; and (6) sometimes a compound with a volatile powder, such as powdered camphor or oxide of zinc, worked into it, in which case, he says, to make the light insensitive to variations of the cur-
12095 rent a considerable mass of matter should be used.

The mode of connection is stated to be molding the lampblack and pure material round the platinum wires where they are joined to the carbon, and after carbonizing them.

The coiling is then described, and it is stated that the inventor has carbonized and used cotton and linen thread, wood splints, paper coiled in various ways, lampblack, plumbago, carbon in various forms, mixed with tar and kneaded, so that the same may
12096 be rolled out into wires of various lengths and diam-
eters, each one uniform in size throughout. There are three drawings, two showing carbons very closely coiled, and one of them being within the bulb, and in each case there are clamps connecting the platinum wires cemented into the carbon with the wires sealed in the bulb. The other figure is of a straight piece of the substance which is to be coiled attached to platinum wires at each end, the figure and description of it in the specification

showing that the coiling and carbonization were to 12097
take place after such attachment.

Then come the claims, which are four in number:

> "(1.) An electric lamp for giving light by incandescence, consisting of a filament of carbon of a high resistance, made as described, and secured to metallic wires, as set forth.
>
> (2.) The combination of a carbon filament,
> within [with] a receiver made entirely of glass, 12098
> through which the leading wires pass, and from which receiver the air is exhausted for the purposes set forth.
>
> (3.) A coiled carbon filament, or strip, arranged in such manner that only a portion of the surface of such carbon conductor shall radiate light, as set forth.
>
> (4). A method herein described of securing the platina contact wires to the carbon fila-
> ment, and carbonizing of the whole in a closed 12099
> chamber, substantially as set forth."

I do not agree that the word "lamp" in the first claim means only the "filament of carbon." The claim is "An electric lamp for giving light by incandescence," which the filament alone could not do. The words "consisting of" are inapt, but the wording of the whole specification is exceedingly inaccurate, and this is only an example of such inac-
curacy. "Containing" would have been a better 12100
word. I construe this claim to mean lamps such as are described, in which the distinguishing features are carbons of "high resistance, made as described and secured to metallic wires as set forth."

This seems to me to make the meaning of the second claim more clear. Having in the first claimed lamps of carbon made as described, the inventor proceeds to claim lamps with the combinations described in the second claim. There are (1) the carbon filament (2) in a receiver made entirely

12101 of glass, (3) through which the leading wires pass, (4) and from which the air is exhausted. All these four things Edison, as is apparent from the early part of the specification, supposed that he had invented. I do not think that he intends to lay more stress on one than on another of them. In fact, the only one as to which it is possible to say there is any novelty was carbon in the condition of a filament. I take from Johnson's Directory the meaning of the words, "a very slender thread."

12102 The third claim relates to the coiling, on which great stress is laid in the provisional and complete specifications, and the fourth is a mode of attachment of the carbon to the wires.

The claims, as I read them, are, (2), a combination of four requisites for a lamp; (3) and (4), claims for two of those requisites separately, and (1), a claim for particular modes of making and attaching two platinum wires to the first item of the
12103 combination, viz., the carbon filament. But claim (2) comprehends lamps containing carbon filaments, however made, and not only those made in the special modes described in the body of the specification and included in claim (1).

The defendants construct incandescent lamps with all the four elements of the combinations described in Edison's second claim. But the filament made by
12104 them is essentially different from anything particularly described in Edison's specification. According to the witness Sellon, the filament used by the defendants is made thus: Cotton wool is dissolved in chloride of zinc slightly heated; the result is a viscous, semi-liquid substance resembling in appearance a strong solution of gum arabic. This is boiled in the receiver of an air-pump to extract all air. Then it is forced through a die with a small orifice, by the pressure of a head of mercury, and the filament so formed is received in a vessel of alcohol,

which solidifies it in the form of a thread. It is 12105
then left for a time in another vessel of alcohol, which dissolves all impurities and leaves it a non-structural thread of cellulose in an extremely pure condition. It is dried, carbonized, and fitted for use in a lamp. If Edison's patent claimed only lamps with filaments such as those particularly decribed in the body of the specification, it is obvious this would be no infringement. In 1879 Edison, so far as appeared, never dreamt of making a carbon filament in this way, but as I have come to the con- 12106
clusion that Edison's second claim is wide enough to include any lamp with a carbon filament; however made, the defendants have clearly infringed this claim.

Then comes the serious and important question whether so wide a claim can be supported. I have already pointed out that the only item of the combination which had any novelty was the use of the filament or "very slender thread" of carbon. Edison had managed to use carbons thinner than 12107
anyone had used previously. The only advantage of a "filament" suggested in the specification is its high resistance by reason of its thinness or small sectional area. There was no invention described in this specification of any new principle. The principle of increasing resistance by diminishing the sectional area of the carbon was known and had been published by Lane-Fox and by Swan before November, 1879. Assuming that Edison had been the first successfully to put that principle in practice, 12108
by the methods described in his specification, did that success entitle him to say, "no one shall make a lamp with a filament of carbon but myself?" Suppose the claim had been thus worded: "I have succeeded in making an electric lamp with a carbon burner—say, 1/100th of an inch in diameter—which gives a high resistance, and I claim a monopoly of all lamps with carbon burners, but thicker than that, however made." Could such a claim be supported? That, in effect, is Edison's second claim.

12109 One of the objections made is that the claim ought to have been worded in some such way as I have just suggested, in order to make it sufficiently definite. In other words, Edison ought to have indicated the exact boundary between his "filament" and such a Carré carbon as Swan has successfully used. From the drawings and from the great stress laid upon coiling the filament, the only object of which seems to be to increase resistance by using a considerable length, I should conclude that
12110 Mr. Edison did not conceive that extreme thinness of the carbon was practicable. Mr. Swan had tried paper, cardboard, and similar materials carbonised, and, if he had not tried a "filament," he had used and obtained considerable success with Carré carbons not more than $\frac{1}{25}$th of an inch in diameter. He was trying these in the form of a hairpin, made and shaped to that form before carbonization; and it seems impossible to say that Edison, by reducing the thickness of the horse-shoe
12111 carbon, had made any vast invention or contributed largely to the knowledge which such inventors as Swan and Lane-Fox already had on the subject. There is authority for saying that if an inventor discovers some new principle and describes a practical mode of applying it, he may have a patent which would prevent another person from applying the same principle by different means. In "*Jupe* v. *Pratt*," *in* 1*st Webster*, Baron Alderson says:

12112 "You cannot take out a patent for a principle. You may take out a patent for a principle coupled with the mode of carrying the principle into effect, provided you have not only discovered the principle, but invented some mode of carrying it into effect. If you have done that, then you are entitled to protect yourself from all other modes of carrying the same principle into effect, that being treated by the jury as piracy of your original invention."

But is there any decision that an inventor who

has discovered a mode of applying a known princi- 12113
ple like this, of increasing resistance by diminishing the sectional area of the carbon burner, can obtain a monopoly of the principle? Sir F. Bramwell in his evidence for the plaintiff, put the case in the strongest and most favorable manner by saying that Edison made the first commercially successful incandescent lamp. Unless that is so, his claim to so large a monopoly would not, in my opinion, be arguable. I proceed to inquire: Did he make a commercially successful lamp; that is, were any of the 12114
modes of making lamps particularly described in the specification commercially successful? In most patent cases, when the validity of the patent is impeached for want of novelty, the most important witness is the inventor. It is usual to put him in the box and expose him to cross-examination. Mr. Edison is in America; but if there were any other reason which prevented his appearing as a witness on the trial, the Court has power to direct an examination in America. He has neither been produced, nor 12115
has any attempt to examine him in America been made; and the objection was raised during the evidence to reading statements made by him in his later patents to show what he really had invented at and before the date of his patent of 1879. I must say that this mode of conducting the plaintiffs' case seems to me to put the defendants at an unusual disadvantage; and I think the Court is bound to prevent them from being prejudiced by it as far as possible. I shall not hes- 12116
itate to refer to the language of Edison's subsequent patents as admissions by him so far as they tell against the claim now made in his name to a large monopoly.

I have before me several patents by Edison in his own or other names. There are amongst others, three in 1878, Nos. 4226, 4502 and 5306; three in 1879, Nos. 2402 and 4576, which is the patent now in question; and subsequently in 1879, No. 5127; in 1880, No. 3765, which has been called in the

12117 argument the bamboo filament patent; and in 1881, Nos. 539 and 1918. Whenever he hit upon any improvement, Edison seems to have applied for an English patent without waiting to perfect the invention, and no one can read the patent in question of 1879 without being struck with the evidence of haste shown by the crude manner and imperfection of description in every part of it. In the later patent, No. 5127, of 1879, Edison gives careful directions as to the mode of carbonizing the strips
12118 of bristol board in molds, preferably of wrought iron. In the bamboo patent, No. 3765, of 1880, he begins by again asserting that the practice, so far as he knows, had been to make carbons of as low resistance as possible, and that he had discovered that the incandescing material should have the highest possible resistance in a very small bulk; and further, that carbons which are purely structural in character alone possess these qualities. By "purely structural" is meant a carbon wherein
12119 the natural structure, cellular or otherwise, of the original material is preserved unaltered; that is, it is not modified by any treatment which tends to fill up the cells or pores with unstructural carbon, or to increase its density or alter its resistance. One object of this invention, therefore, is to provide such carbons, and means and method for their manufacture. He then mentions several kinds of vegetable fibre, among others the hard, glossy exterior of the bamboo cane. Elaborate directions are given for shap-
12120 ing and carbonizing these fibrous substances, and the claims include (1) An incandescent conductor formed of one or more carbonized natural fibres; (6) A slip or filament made of bast or fibre-like cane or bamboo; and (12) The method of forming them and then carbonizing them. In all, there are in this patent 44 claims. To say that purely structural carbons alone possess the requisite quality was altogether an error. Swan's unstructural carbons, parchmentised, as they are called, are among the best burners known.

The plaintiffs have been challenged again and 12121
again during the cross-examination of their witnesses to prove, if they can, that any lamp with a burner, made according to the description in the body of the specification of November, 1879, has been brought into the market in England or in America. No evidence of this has been given, and I conclude that there was no commercial use of the invention of that kind. Until he had taken out his subsequent patents it seems that Edison did not introduce any lamp to the public. Dr. Hopkin- 12122
son saw some, he says, probably in 1881, made under one of these later patents. In that year, 1881, Edison exhibited some at the Paris Exhibition in the month of September. These were bamboo filament lamps, and this was the first public exhibition of these lamps, at any rate in Europe. No doubt this is not conclusive that the invention had no utility, because, as it has been argued, improvements may have been invented so rapidly as to have superseded the original invention before it could be brought 12123
out publicly; but it is somewhat difficult to make out that lamps described in the specification of 1879 were commercially successful, if none were ever brought into the market; and the success of a lamp made under a subsequent patent, like the bamboo lamp, which has been largely used, can hardly support a previous patent which did not describe it.

It has been attempted to argue that the patent of 1879 did include the bamboo filament, first, be- 12124
cause the second claim includes all filaments of carbon; and secondly, because in the body of the specification Edison says: "I have carbonized and used wood splints." I can only say I admire the courage of such an argument. The question is, whether the specification particularly describes a commercially successful lamp so as to support so wide a claim. This is not answered by saying that the claim is wide enough to include all filaments, and therefore they must be taken to be all de-

12125 scribed. And with respect to so much of the argument as rests upon the words "wood splints," those words do not describe anything so as to show workmen how to make them. Indeed, they are not intended as a description, but occur in a sentence which may be properly called a passing observation, as though here, and in other parts of the specification, Edison was simply putting on paper a cursory allusion to experiments, how made, and whether successful or not, he does not pause to
12126 say.

Filament made according to the several descriptions in the specification have been made, carbonized and used by way of experiment in order to show that it was possible to make them. Upon this there was a considerable conflict of evidence. Mr. Crookes, the celebrated chemist, followed the terms of the specification as he understood them, detailed experiments which he had made which failed completely, and declared that he was quite
12127 unable to make the carbon successfully from the instructions given. On the other hand, a young man named Gimmingham, who had had some scientific education, was produced as a witness for the plaintiffs, and he deposed that he had, from the specification alone, without any special instruction, made the carbons successfully without difficulty. Other witnesses supported Mr. Crookes on the one side and Mr. Gimmingham on the other.

Some of the reasons for the success of one set of
12128 these experiments, and the failure of the others, was pretty clear; others I could not understand; and at my suggestion the parties agreed that the experiment should be repeated in the presence of Prof. Stokes, whom they chose as an independent expert, who should report the result to the Court. I have that report which the parties have seen, and it is obvious from it that no one with the knowledge that existed in 1879, unless he were as practised as Mr. Edison himself, or Mr. Swan, could have made a successful electric

incandescent lamp from Edison's description, with- 12129
out a long series of careful experiments, and very many failures in his attempts.

With respect to the commercial success of the invention as tested by these experiments, I find from the report and supplemental table of results which has been handed to me as an agreed statement, that out of 100 lamps some broke down at once, 13 lasted less than 10 hours, 11 more less than 20, 8 more less than 40, and only six above 40 hours, of which four were unbroken at 60 hours, and of these four 12130
there is no further record. That is far from commercial success. No system of electric lighting could be maintained, except at an expense which could not practically be incurred, with lamps of such short life as these; and this explains most satisfactorily why Edison never sold lamps made according to the specifications of 1879.

In considering the sufficiency of this specification, it must be remembered that in 1879 there was 12131
no trade or business of manufacturing electric incandescent lamps. Lane-Fox, Edison, Swan, and other inventors had given much time and attention to the subject, but except such persons there were none who had any special knowledge in the matter. The *dicta* that may be found in some cases that the specification of certain patents may be read as addressed to adepts in the particular trade or business do not apply. For this reason it was essential that the specifications should be carefully explicit. It 12132
ought to be such as would enable an intelligent working man to make an incandescent lamp without having to try experiments. Take, for example, the process of carbonizing filaments. In his subsequent patents Edison gave elaborate directions for this. In this patent, though dealing with filaments made of putty compounded with lampblack and tar, cotton thread, thread coated with the putty, the putty combined with camphor or oxide of zinc, and other substances for the manufacturing of carbon fila-

12133 ments, he contents himself with saying that the cotton thread is to be properly carbonized; the fibrous vegetable substance is to leave a carbon residue after heating in a closed chamber; the tar putty is to be carbonized in a closed chamber by subjecting it to a high heat. Nothing is said to indicate what sort of closed chamber, of what it is to made, how it is to be used, the degree of heat to be applied, nor the length of time during which the heat is to be kept up. There is no mention of any packing
12134 to be used in the chamber, nor of any precaution to prevent distortion of the filaments during carbonization. There was no industry in 1879 in which carbonization of anything so small as a filament was used. It was known to chemists that one mode of carbonizing was to pack the substance to be carbonized in powdered charcoal, which when heated, gradually combined with any oxygen which might be in, or might during the process find its way into, the vessel used, and thus the substance to be car-
12135 bonized might be protected from being consumed. This mode of carbonizing is mentioned in the patent of Pulvermacher, for making arc carbons, before 1879; but this certainly was not generally known, and it is not alluded to in Edison's patent, which is now in question. Carbonizing filaments in an ordinary fire clay crucible, without such packing, will not do. They are consumed, and nothing but ash remains. It seems that it can be done in an iron box with a lid carefully fitted, if the heat be gradually
12136 applied, and for a short time, but the carbons now used commercially are exposed to furnace heat, applied gradually at first, and kept up for periods of from 11 to 14 hours, and they are carefully packed in powdered charcoal and wound on a frame contrived so as to yield as they contract. I have no reason to suppose that anything like that time, or so great a heat, could be successfully used with filaments in an iron box without packing. I am satisfied that considerable experiment would have been necessary in 1879 to discover what sort of closed

vessel would do, whether packing was necessary, 12137
and what amount of heat, and for how long, and how it was to be applied. The specification seems to me altogether insufficient in these respects.

Then, as to the tar putty, it seems it may be made by kneading the materials with some exertion for an hour and a-half. The only direction given is that it is to be kneaded until it assumes the consistency of thick putty. I have no reason to doubt that Mr. Crookes honestly tried to make it and failed. A workman would not have fared 12138
much better, and could not have succeeded without much experiment. The filament, which is to have a volatile powder, like camphor or oxide of zinc worked into it, has been imitated by dusting a tar putty filament with these materials very carefully, but I do not think it has been done in the experiments as Edison intended. The description is vague, but I conclude from the mention of a volatile powder, that the object was to use something that would volatilize in the process of 12139
carbonizing, and that some considerable mass or thickness of carbon was to be used which would be left by such volatilization in a very porous condition, and would thus have its resistance increased. The experiments seem to me a mere pretence of carrying out this. No such carbon has been shown to be of any practical utility. Considerable evidence has been given to show that coating carbon with a non-conducting, non-carbonizable substance would cause its destruction when 12140
incandescent by the decomposition of the coating, the oxygen in which, when free, would destroy the carbon filament. The evidence leaves it somewhat in doubt whether this occurs before an actual fracture of the carbon, occasioning the intense heat of an arc.

I do not think it necessary to observe at length other objections that were made to the specification. One of those related to the effect upon the platinum

12141 wires of exposing them, together with the burner, to the process of carbonization, which, as I have mentioned, the drawing Figure 2, and the description of it, show that Edison intended. Another is the use of a copper helix to assist in coiling the burner; another is the use of the coil of carbon which Edison describes, for the purpose of increasing the resistance by length without enlarging the radiating surface in proportion to the length of the burner. This seems to have
12142 been abandoned as useless.

My opinion is that the patent of Edison's, No. 4576, of 1879, is invalid—first, because the second claim is for a monopoly of the incandescent lamps containing a filament of carbon for a burner, which claim, I think, is far too wide, considering how little Edison had actually invented; secondly, because his specification does not describe a lamp which
12143 ever became, or, as I think, could have become, commercially successful; thirdly, because the directions therein contained are so insufficient that no one could have made the carbons he describes without considerable previous experiment; fourthly, because one of the processes described—viz., mixing the carbon with a volatile powder—I believe to be practically injurious if done as Edison directs; fifthly, because the coating with a non-conducting, non-carbonizing substance, if not injurious, is of no
12144 practical utility; sixthly because the same may be said of coiling the filaments, on which the patentee lays great stress.

This patent of Mr. Edison's, No. 4576, of 1879, has been the subject of litigation in a previous suit between the present plaintiffs and Messrs. Woodhouse and Rawson, who were manufacturing incandescent lamps and were sued by the plaintiffs for infringements. The case went to the Court of Ap-

peal, and both in the Court of First Instance and in 12145
the Court of Appeal the patent was treated as valid, though apparently with some hesitation. I am bound by these decisions, and should follow them, of course, whether I agreed with them or not, if the evidence in the two cases were the same. But that is not so. On one point, which Lord Justice Cotton seems to have thought essential, the Courts were completely misled. They were given to understand that the carbon burner in the lamp exhibited by Swan before the date of Edison's patent was shaped 12146
after and not before carbonization. It is now admitted this was not the fact. It was a carbon made by Carré and used as made by him without alteration. But, further, I am told that there was no evidence in that case as to the difficulty of making the carbons described in Edison's patents from the description in the specification. I understand that no contest took place as to the sufficiency or utility of any part of Edison's patent, and that nothing like the evidence as to the previous knowledge on 12147
the subject was given in that trial which has been adduced in this. With respect to the construction of the patent, the opinion which I have expressed agrees with that of the majority of the learned Judges in the Woodhouse and Rawson trial. The case has been brought before me with such an elaboration of evidence on every point that I think myself bound to act upon my own opinion, believing as I do that if the same materials had been before the learned Judges in the other case they would 12148
have arrived at the same conclusion as I have done.

The other patent in question in this action is Cheesbroughs, No. 4847 of 1878, amended by disclaimer dated November 12, 1884. The specification describes and claims a method of preparing the illuminating portion of an electric

12149 lamp, and also a material for the manufacture of illuminating carbons. Shortly stated, the carbon to be prepared is surrounded with a carbon gas or liquid, and then heated intensely by the passage of the electric current. This causes a decomposition of the surrounding hydro-carbon and the deposit upon the heated surface of an extremely dense form of carbon, such deposit being in greater quantity upon the hotter—that is, the thinner—portions. The specification states that "carbon of the ordi-
12150 nary sort, when heated by the electric current, exhibits points and lines of unequal brilliancy. Carbons prepared by this process when so heated glow with a uniform brilliancy throughout."

A French chemist, Despretz, in experimenting on the reduction and volatilization of carbon, discovered that when the carbon was heated in an atmosphere of hydro-carbon this deposit occurred and interfered with his operations; and he describes this in a paper which was published in England some years before
12151 1879. But Despretz did not utilize this product in any way, and his experiments had nothing to do with electric lighting. Assuming that Cheesbrough derived his knowledge of the mode of producing this material from Despretz's paper, his invention consists in applying it for the purpose of making uniform the light-giving power of a piece of carbon when heated by the electric current; and the beauty and merit of the invention consists in thus enabling an imperfect carbon, by a sort of automatic opera-
12152 tion, to improve and perfect itself. I have no doubt that this is a good subject for a patent. I had more hesitation upon the claim for the material, which certainly was not discovered by him; but that is not the whole of the claim. It is for "a material for the manufacture of the illuminating conductors of electric lamps produced by electrically heating carbon in a carbon gas." That does not prevent any one from making the same material and using it for other purposes. The claim is really for the use of the material for the

burner of an electric lamp. This seems to me 12153
equally valid.

Another objection—that pencils cut from the lime cylinder coated with carbon would not make effective carbons—seems to me to arise from a misconstruction of the specification. It is not the lime cylinder, but the deposit of carbon which is to be made into burners. The defendants have used this process of Cheesbrough's, but they say for a different purpose. Their object is to bring all their carbons to one standard of illuminating power, an 12154
operation for which they have invented a somewhat cacophonous word—"standardising." But Seldon, one of their principal witnesses, admitted that the process would cure any inequalities of light-giving surface in the particular carbon so treated. These, he says, in their celluous carbon threads seldom occur.

However, I cannot resist the conclusion that the defendants, by this use of a process for carbons of incandescent lamps, are infringing 12155
Cheesbrough's patent. The plaintiffs' reply in this case was, unfortunately, interrupted. The Attorney-General asked leave, if the Court wanted more assistance on any point, to add somewhat to the reply. I have not thought it right to trouble him further. Every point has been put again and again to the scientific witnesses. Twenty-one of the working days of the Court have been occupied by this case. I have not arrived at the conclusion I have intimated without thought and care, and I do not 12156
think that further argument would be a useful expenditure of public time. I must therefore decline to trouble counsel any more in the case. I have been provided with a copy of the print of the shorthand notes. They contain, as is, perhaps, inevitable in such a case, a considerable number of verbal inaccuracies, some of which completely distort the meaning of what was said.

The action, as far as it relates to Edison's patent, 12157 of 1879, must be dismissed with costs. There must be an injunction to prevent any further infringement of Cheesbrough's patent, and the defendants must pay the costs of the action so far as it relates to that. The costs must be settled in the usual way.

SIR HORACE DAVEY: It is not necessary to ask your Lordship under the act to certify that our objections were reasonable to propose.

MR. JUSTICE KAY: As far as I remember them they were all reasonable.

12158 SIR HORACE DAVEY: That will be sufficient. Perhaps your Lordship will think this case is of sufficient importance to allow the costs on the higher scale? I think the words are "of sufficient importance and difficulty."

MR. JUSTICE KAY: Yes.

MR. BREMNER: I have to ask your Lordship for a certificate.

MR. JUSTICE KAY: You can take the certificate as
to the Cheesbrough patent that the validity came
12159 into question. It was previously brought into
question, I was told, and I think you are entitled
to the costs as between solicitor and client.

SIR HORACE DAVEY: The Anglo-American Brush Company are third parties, but I think it will be more convenient, as no question was raised as to that, that they be put in direct relation with the plaintiffs, to which I suppose there will be no objection.

MR. BREMNER: No. I think not.

12160 MR. ASTON: Would your Lordship allow me to ask whether on the Edison patent your Lordship would not be pleased to direct that we should have the costs of those issues on which we were successful.

SIR HORACE DAVEY: His Lordship has not found you successful.

MR. ASTON: There is no question of infringement.

MR. JUSTICE KAY: I do not see how it is possible to infringe an invalid patent.

MR. ASTON: I know that has been said more than 12161
once, but the question of infringement is a question of
fact, which is separate and your Lordship dealt with it
separately in your judgment.

SIR HORACE DAVEY: Are there any extra costs for infringement?

MR. ASTON: Oh, yes; we were obliged to call witnesses upon it.

MR. JUSTICE KAY: You did not give a fraction of evidence about infringement. It was all admitted by Mr.
Sellon. 12162

MR. ASTON: We were obliged to be ready, at all events. Then there is that other issue with regard to the alleged anticipation by the user of Swan's lamps. Your Lordship was with us upon that.

MR. JUSTICE KAY: I think it is very inconvenient to make any distinction in a case where it seems to me the plaintiffs have failed. I am not inclined to make any distinction.

MR. ASTON said it was done in the Badische Anilin
case, and the Court of Appeals held it to be a proper 12163
thing to do.

MR. JUSTICE KAY: I do not think it right to do so. I think you ought to pay the costs of the action.

12164

12165 **Defendant's Exhibit Decision of the Royal Kammergericht.**

[On Appeal in the suit of Edison vs. Naglo Bros.]

Notar im Bez. d. K.P. Kammer-gerichts. O. Hentig.

Beglaubigte Abschrift.

(Original ohne Stempel.)

12166 STEMPEL-MARKE. M. 1½ M. Berlin, d. 6 11.90. O. Hentig. U. 729. 85. VI.

Im Namen des Königs!

12167 Verkündet am 5. Mai 1890. gez. Papke, Gerichtsschreiber.

In Sachen

der Handelsgesellschaft Gebrüder Naglo und deren Inhaber

1) Fabrikant Emil Naglo,
2) Fabrikant Wilhelm Naglo,

zu Berlin, im Prozess vertreten durch Rechtsanwalt
12168 Lazarus und Rechtsanwalt Lané zu Berlin, Beklagte jetzt Berufungskläger,

gegen

1) den Ingenieur Thomas Alva Edison zu Menlo-Park, New-Jersey, Vereinigte Staaten in Nord-Amerika, vertreten im Prozess durch Rechtsanwalt, Justizrath Wilke zu Berlin, Kläger jetzt Berufungsbeklagter,

2) die Allgemeine Elektricitätsgesellschaft zu Berlin, vertreten durch die Vorstandsmitglieder, Ingenieur

Ernst Rathenau und Felix Deutsch, Nebeninter- 12169
venientin im Prozess vertreten durch Rechtsanwalt Alexander Katz in Berlin,

erkennt der sechste Civilsenat des Königlichen Kammergerichts zu Berlin, unter Mitwirkung folgender Richter:

1) des Geheimen Ober-Justizraths Gottschewski, als Vorsitzenden,
2) des Kammergerichtsraths Keyssner,
3) des Kammergerichtsraths Hönemann, 12170
4) des Kammergerichtsraths Dr. Mencke,
5) des Landgerichtsraths Dr. Müller,

für Recht:

I. Das Urtheil des Königlichen Landgerichts I. zu Berlin, Civilkammer II., vom 9. März 1885 wird dahin abgeändert:

auf die Berufung der Beklagten

Klägerin wird mit dem Antrage, die Beklagte 12171
zu verurtheilen den Betrieb der von ihnen vor der Klagezustellung in Benutzung genommenen nach dem dem Joseph Wilson Swan ertheilten Deutschen Reichspatente No. 13071 hergestellten elektrischen Glühlampen einzustellen und sich fernerhin des Gebrauches, des Inverkehrsbringens und des Feilhaltens solcher Glühlampen zu enthalten

abgewiesen. 12172

II. Die Berufung des Klägers wird zurückgewiesen.

III. Die Kosten des Verfahrens trägt der Kläger

VON RECHTS WEGEN!

[NOT FILMED: PAGES 5044-5054]

Defendant's Exhibit "Decision of the Royal Kammergericht," on Appeal, 12217

In Suit of

Edison *vs.* Naglo Brothers.

CERTIFIED COPY. 12218

(Original without stamp.)

(Stamp) U. 729.85. VI.
Announced May 5, 1890.
Signed: PAPKE,
Clerk of the Court.

12219

IN THE NAME OF THE KING!

In the suit of the Mercantile Firm of NAGLO BROTHERS and the owners thereof,

1, Emil Naglo, manufacturer,

2. Wilhelm Naglo, manufacturer,

of Berlin, represented in the case by attorney Lazarus and attorney Laué of Berlin, now appeal-plaintiffs, 12220

against

1. Thomas Alva Edison, Engineer, of Menlo Park, New Jersey, United States of North America, represented in the case by attorney, counsellor-of-justice Wilke, of Berlin, plaintiff, now appeal-defendant;

2. The General Electric Company of Berlin (Die Allgemeine Electricitätsgesellshaft zu Berlin), rep-

12221 resented by members of the directory, Engineer Ernst Rathenau and Felix Deutsch, intervenor in the cause, represented by attorney Alexander Katz, of Berlin;

The Sixth Civil-Senate of the Royal Chamber Court of Berlin (Königliche Kammergericht) composed of the following judges:

12222 1. Privy Chief Counsellor of Justice Gottschewski, presiding;

2. Counsellor of the Chamber Court (Kammergericht), Keyssner;

3. Counsellor of the Chamber Court ("), Hönemann;

4. Counsellor of the Chamber Court ("), Dr. Mencke;

12223 5. Counsellor of the District Court (Landgericht), Dr. Müller;

renders judgment:

I.—The judgment of the Royal Landgericht (District Court) I. of Berlin, Civil Chamber II., of the 9th of March, 1885, is changed as follows:

Upon the appeal of the defendants the plaintiff's motion to condemn the defendants to dis-
12224 *continue the running of incandescent lamps put in use by them before the serving of the complaint, and made according to the German Imperial patent No. 13,071, granted to Joseph Wilson Swan, and to refrain from further using, introducing into trade and keeping for sale such lamps, is denied.*

II.—The appeal of the plaintiff is dismissed.

III.—The plaintiff bears the costs of the proceeding.

IN THE COURSE OF LAW! 12225

STATEMENT OF FACTS.*

There has been read in the present proceeding by the defendants the motion of the 22nd of April, 1885, (Vol. I., p. 191) and of the 27th of January, 1886 (Vol. I., p. 254); by the plaintiff the motions of the 7th of May, 1885, (Vol. I., p. 196) and of the 4th of March, 1886, (Vol. I., p. 280).

The General Electric Company of Berlin has ap- 12226
peared as intervenor and been admitted.

The judgment of the lower court has been read. It is referred to. Furthermore, there have been read the text of the Edison patent 12,174 (Vol. I., p. 11), the order for taking evidence of May 17, 1886 (Vol. I., p. 343), the opinion of Prof. Paalzow (Vol. II., p. 3), the opinion of Prof. Slaby, (Records, U. 905. 86, VI., Vol. II., p. 27), the proceedings of October 28, 1887 (Vol. I., p. 479), the opinion of Prof. Paal-
zow of June 29, 1888 (Records U. 905, 86. VI., Vol. 12227
II., p. 107), the order for taking evidence of February 2, 1888 (Vol. II., p. 47), the proceedings of March 6 and March 16, 1888, (Vol. II., p. 52, 54), the decree of March 11, 1889, the opinion of Prof. Kohlransch, (Vol. II., p. 84 & f).

The defendants, on the basis of the opinions, argued for the dismissal of the plaintiff.

Plaintiff argued in support of the views which are laid down in the paper of May 5, 1890, which is
referred to. He asserts that by patent 12,174 there 12228
has been patented a lamp with carbon fiber, without regard to the material of which it is made. Further-

* "ORDER. The Statement of Facts of the judgment is supplemented as follows:
"The attorney of the plaintiff and the intervenors have read the contents of the patent-application which is to be found in the records under U. 729, VI., Vol. I., p. 300 & *ff*.
Berlin, June 23, 1890.

ROYAL CHAMBER COURT,
Sixth Civil Senate.

Certified:
RABEIN, Clerk of the Court.
L. S."

12229 more, the plaintiff reads the opinion of the Patent Office of December 30, 1886 (U. 905.86. VI., Vol. I., p. 69) and of February 8, 1888, (*ibid.* Vol. II., p. 95); also, the decision of the Patent Office of February 24, 1884, which established an executory decision between the parties. Plaintiff refers to the decision of the Reichsgericht (Court of the Empire), first Civil-Senate, of January 13, 1885, (Reports, Vol. 14, 1876 and *ff*) and offers to prove by the tes-
12230 timony of railway director Willert and engineer Seibt, that the Edison lamps made under patent 12,174 were in use in the Edison factory and in a district of the City of New York before January 1, 1880. Eventually the oath is tendered to the defendants concerning this fact. Thus he asserts practical availability for the trade to be established.

The defendants make denial.

Moreover, the parties argue at length for their motions.

12231

GROUNDS OF THE DECISION.

We need not go into the details of the decree of the 2nd of February, 1888, (Vol. II., p. 47) and the result of the evidence; for, even if it is taken for granted that the defendant, under patent 13,071, has to do with such incandescent lamps as are specified in the text of the judgment and in the motion of plaintiff, even then the motion of the plaintiff is
12232 unfounded.

The patent 12,174 is to be found in Vol. I., p. 11. The Gimmingham patent 19,851 is to be found in the present records, p. 21.

Sec. 20 of the patent law states how the application on an invention for which a patent is sought must be made, what its contents must be. While it may be going too far to say that what the applicant for a patent claims as his new invention must be defined with precision in the patent claim—an expression which is not known to the patent law—

still there can be no doubt that what is to be protected by the grant of a patent is limited with ex- 12233
actness by the patent claim when taken in connection with the patent description. This has been kept in view throughout in the opinion of Prof. Dr. Paalzow, and has been expressed fundamentally, sharply and precisely in the opinion of Prof. Kohlrausch. Although Prof. Slaby has tried to keep within this limitation, he has not done it with the necessary pre- 12234
cision, as can be seen from the interpretation of the patent claim which he tried to give at p. 50 of the records.

This alone is a sufficient reason for treating the opinion of the latter expert as inferior to the other opinions. But it is to be especially remarked that the scope of question 1a of the evidence-order of October 7, 1886, (Vol. I., p. 240) appears to have been misunderstood by this expert (opinion, Vol. II., p. 42). By no means could there be imposed 12235
thereby the same task which the patent office had to fulfil when the patent was applied for; but it was the object of the Court to learn with the utmost certainty what was known already, in order to understand clearly the contents of the patent granted to Thomas Alva Edison.

This task has been gone through with and finished successfully by the two other experts, as can be seen especially in the determination of the meaning of the word "faden" (*filament or thread.*) 12236

Since the opinions of Paalzow and Kohlrausch agree on the essential points, the Court has taken into consideration only the opinions of these two experts.

Very justly Prof. Kohlrausch points out the fact that the text of the patent description 12,174 is extraordinarily obscure (Vol. II., p. 219;) that much is named and spoken of that is not in any way described. The reason for this the expert gives to understand very well in other places in his opinion

12237 (p. 225.) The uncertainty of expression was not accidental; in the uncertainty a protection for the future was to be provided; the possibility was to be opened of covering under the granted patent inventions which had not yet been made at all, (Vol. II., p. 226). If such an attempt be made, the patent cannot be extended beyond its clearly discoverable contents. Such an extension would be a violation of the rights of later inventors. The
12238 vagueness of expression cannot inure to the advantage of the owner of the patent.

Question has been made, whether the patent 12,174 has been of any commercial availability at all. Prof. Kohlrausch evidently treats this question with cautious reserve, because it was hard to get a clear view of the times and places. Plaintiff has offered proofs on this point. This disputed question was not to be further discussed; it cannot
12239 be discussed in the present litigation whether the Edison patent ought to have been not granted at all, or at least not in that form; but the patent is to be considered as existing in accordance with law, and it is only to be decided whether the domain of the patent has really been invaded by the defendant.

The question whether the description of the patent really answers the requirements of Sec. 20, is to be determined by these words of the law:
12240 "that thereby the use of the same by another expert appears possible." Now the standing of the patent 12,174 can in no wise be questioned by the present Court on the ground that a definition of the invention is not possible on the basis of the description, for the question whether the patent was to be granted or not, was to be decided by the Patent Office alone.

But if, as is the present case, it has to be decided whether the protected territory of a patentee has been invaded by a later inventor, inquiry must be

made, concerning the alleged infringement, whether 12241
the description in the patent is such that thereby such information was given to the reading expert that in making the object intended by the patentee he had only to follow his instructions, or whether his own independent new-creating activity was necessary to attain the end.

Although, as we have already mentioned, Prof. Kohlrausch treats this question with reserve, Prof. Paalzow gives his opinion on this point with full 12242
precision and certainty, with statement of reliable reasons. (Vol. II., p. 27). And this certainty is fully justified.

Prof. Kohlrausch declares (Vol. II., p. 237) the words "properly carbonized" not to answer the requirement of Sec. 20, paragraph 1. This question has already been the subject of discussion in the session of the 28th of October, 1887, set for hearing of witnesses, (Vol. II., p. 11). The attempt of Prof. Slaby to give a definite meaning to the words "prop- 12243
erly carbonized," although already discredited by Prof. Paalzow, has now been entirely disposed of by the further opinion of Prof. Kohlrausch. The statement of Prof. Paalzow in the proceedings of the 28th of October, 1888, (Vol. II., p. 13), that by the use of the Sawyer-Man patent a very slender incandescent filament could be manufactured, has been misunderstood by the plaintiff. If Edison had made use of the patent description of the Sawyer-Man patent, he would, according to Paal- 12244
zow's meaning, have secured an incandescent filament. This utterance, which needed to be further explained by the expert, is of no importance for the present question, which is settled by these words of Prof. Kohlrausch:

> Question 4: "By the words '*properly carbonized*' is there given such a description "as is required by Sec. 20, par. 1, of the "patent law"; I answer, referring to the explanations given on pp. 45-49, with—No.

12245 By this the expert has in nowise answered a question of law, nor interpreted the law, but in fact only as an expert expresses the opinion that a carbonization such as is required for conveying electricity through a carbon filament, cannot be produced by the words of the patent. The reasoning of the expert is convincing to the Court.

As it is thus established that the thing for which Edison claimed a patent cannot be manufactured on
12246 the basis of the patent description 12,174, and as only the thing described in the patent is patented, it follows that the one who after the granting of the patent has manufactured something that may be within the reach of the literal statement of the object expressed in the patent, cannot have violated the patent, but has worked by an independent process. Now if it is proved that the Swan United Electric Light Company manufactures salable incandescent lamps, this cannot be done in violation
12247 of a process not described in patent 12,174. If plaintiff desires to exercise a veto on the basis of the patent, the burden lies upon him of proving that there has been an invasion of the territory circumscribed by the patent. This evidence is wanting, and therefore there follows as of course the reversal of the decision of the first instance.

If, on the other hand, the plaintiff refers to the
12248 decision of the Patent Office of January 24, 1884, by which the suit of the Swan Company for the annulment of patent 12,174 was dismissed, it is not seen how therefrom it should follow that a manufacture in accordance with patent 13,071 is an infringement upon the patent of plaintiff. The existence and the legal validity of patent 12,174 are, as stated, beyond question, but it is matter of question what has really been patented. Upon this point, in cases of litigation, it is not the province of the Patent Office and the Reichsgericht (Court of the

Empire) as final instance to make decision, but of the ordinary courts. 12249

In deciding these questions it does not matter what the patentee Edison may have desired to have patented, but only what is patented according to the words and the contents of patent 12,174.

Plaintiff has sought to establish that there has been patented to him generally,

> An electric lamp which gives light by incandescence, and which consists in substance 12250
> of carbon fibre of high resistance.

He refers to the decision of the Reichsgericht, 1 Civil-Senate, of June 13, 1885 (Decisions, Vol. XIV., p. 76), and assumes that it is the article of manufacture which is patented to him. What the Reichsgericht (*Ibid.* p. 78) says in regard to a patented article of manufacture, is in harmony with Sec. 4 of the patent law, and is beyond doubt. Mistake of the plaintiff is that he claims for himself as 12251
patent domain, the whole domain of incandescent lamps.

The lighting and illuminating power of the electric current conducted in a certain way, was known long ago; also the laws of Joule and Ohm (see Paalzow, Vol. II., p. 67); electric lamps had been manufactured long before Edison (Paalzow, Vol. II., p. 55); also carbon, or, generally, illuminating bodies of high resistance, were long known as serviceable (Kohlrausch, Vol. II., p. 210); thus by no 12252
means is it an incandescent lamp as an article of manufacture that has been patented, but the mode of making an incandescent lamp, whereby it is not excluded that thereby the patenting of a manufactured article is included.

Reference may here be made to the decision of the Patent Office of January 24, 1884, in which a number of older incandescent lamps are mentioned, and in which it is correctly said:

"The contested patent 12,174 protects a

12253 "certain kind of electric incandescent lamps, "whose chief peculiarity consists in the use "of carbon fiber of high resistance, for the "purpose of producing light."

Only a certain species of electric incandescent lamps was protected, not the genus of incandescent lamps. In opposition to this, there was the pretension that a patent already protects things to be invented in the future.

12254 While the use of the glass-body, the establishment of the vacuum, the use of the platinum wires, are not contended for by defendant (*plaintiff*) as being contained separately in the patent, he does contend for the carbon fiber of high resistance for the purpose of light-giving. The end to be obtained was established by the laws of Joule and Ohm:

> "The problem which was to be solved, "that is, to construct a lamp with carbon "conductors of very high resistance, was
> 12255 "known" (See Kohlrausch, Vol. II., p. 215).

It is convincing when Prof. Kohlrausch (Vol. II., p. 216) states that this problem had already been solved by Sawyer and Man, with a better prospect of success than in patent 12,174.

The plaintiff lays great stress upon the word "faden" (*filament or thread*). Prof. Paalzow, upon request, has in his second opinion perfectly explained the use of this word in his first opinion.
12256 Prof. Kohlrausch stands in complete agreement with him. The word, at first perhaps of undetermined purport, in course of time has taken on a definite and no longer doubtful meaning for the light-giving body.

Defendant [*plaintiff*] claims every carbon filament so patented, and in support thereof rests upon the statement of the patent: "the inventor has "carbonized cotton and linen thread, wood-"splints, paper."

In his opinion, Prof. Paalzow, (Vol. II., p. 662,

ff.) explains to the Court in a convincing manner, 12257
why Edison was prompted to make mention here of these his experiments. Prof. Kohlrausch explains this in another way (Vol. II., p. 226) and comes to the same conclusion.

It is already recognized in the decision of the Patent Office of January 24, 1884, that by the term "Kohlenfaser" (fiber of carbon) in patent 12,174, there is understood not absolutely every carbon of vegetable origin, but only the peculiarly made and 12258
shaped carbon filament?

Prof. Kohlrausch, in accordance therewith, concludes to answer the question:

> "By patent 12,174 is the production of "carbon filaments generally and altogether "patented in such way that every produc-"tion of carbon filaments without the per-"mission of the patentee of 12,174, is an in-"fringement upon the patent;" 12259

in the negative (Vol. II., p. 234). Reference is here made to his reasoning on this point, which has appeared to the Court to be convincing; and the same is to be considered as a part of this decision.

As a consequence it already follows that the plaintiff has not by virtue of patent 12,174 the right of opposition against every incandescent lamp manufactured, etc., elsewhere, nor against every carbon filament manufactured or used elsewhere.

12260

Next Prof. Kohlrausch proceeds, in his opinion, to the settlement of the question:

> "In Swan's improvement in the manufacture of carbon loops for electric lamps, German Imperial patent 13,071, is there effected by the thread of cotton yarn treated by means of parchmentization, such an innovation that thereby all violation of the patent

12261 right secured by the Edison patent 12,174 (patent claim—) is excluded?"

The expert has answered this question in the affirmative.

The Court adopts the reasoning of the opinion as its own, as the same has been convincing to it.

The same holds good for the answer to the question proposed at the end of the order of July 2,
12262 1888, which the expert correctly states as follows:

> "Is the union of the carbon filament with the platinum wire after carbonization (such as is described in the Gimmingham Imperial patent No. 19,851), as compared with a welding before carbonization (Edison patent 12,174, claim 3), something so new that by reason thereof a violation of the Edison patent in general, and especially of claim 3, is excluded, and an altogether new and patentable light-giving body is produced?"

12263 The expert answered this question in the affirmative.

Accordingly it follows that the complaint of the plaintiff was unfounded, and judgment as above had to be given.

The question of costs is settled in accordance with Sec. 87 of the Code of Civil Procedure.

Signed: GOTTSCHEWSKI, KEYSSNER, HÖNEMANN, MENCKE, MÜLLER.

Done at Berlin, May 30, 1890.

12264 [L. S.] (Signed) RUHBEIN,

U. 729. 85. Clerk of the Court, VI Civil-Senate of the Royal Kammergericht.

VI. 4123

I hereby certify that the foregoing copy agrees verbally with the original laid before me.

Berlin, the 6th of November, 1890.

(Signed) OTTO HENTIG.

[L. S.] Attorney at-law and Notary in the District of the Royal Prussian Kammergericht.

Defendant's Exhibit Report of Professor Kohlrausch. 12265

I. In the suit U. 729/85 of THOMAS ALVA EDISON, of Menlo Park, N. J.,

versus

The Mercantile Firm of NAGLO BROS. 12266

II. In the suit U. 905/86 of the "Swan United Electric Light Company, Limited," of London,

versus

The Joint Stock Company, "The German Edison Company for Applied Electricity."

III. In the suit U. 773/85 of the "Edison Electric Light Company, Limited of New York," 12267

versus

R. EISENMANN, of Berlin.

By decree of the Royal Chamber Court of Berlin, of the 11th of March, 1889, the following six questions have been presented alike in the three cases: 12268

(1.) At the date of the Edison German-Empire patent No. 12,174, was the use of a carbon thread (Kohlenfaden) in every form, novel?

(2.) By patent No. 12,174, is the production of carbon filaments (Kohlenfäden), patented broadly and generally in such way that every

12269 production of carbon filaments without the permission of the owner of patent No. 12,174 is a violation of the patent?

(3.) In patent No. 12,174, is the manufacture of a carbon filament (Kohlenfaden) described in such manner that thereafter a carbon filament for an electric lamp of commercial availability can be manufactured by an expert without the aid of other patents, espe-
12270 cially of patents and inventions of a date later than the 27th of November, 1879?

(4.) By the words "properly carbonized," is there given such a description as is required by § 20, Art. 1, of the patent law?

(5.) In Swan's improvement in the manufacture of carbon loops for electric lamps, German Imperial Patent, No. 13,071, is there effected
12271 by the use of a thread of cotton yarn prepared by means of parchmentization, such an innovation that thereby every violation of the patent right secured by the Edison patent, No. 12,174 (patent claim No. 1) is excluded?

(6.) Is the uniting of the carbon filament (Kohlenfaden), with the platinum wires after carbonization, as shown by the Gimmingham German Imperial Patent. No. 19,851, as com-
12272 pared with a welding before carbonization (Edison patent, No. 12,174, claim 3), something so novel that by reason thereof a violation of the Edison patent generally, and especially of claim No. 3, is excluded and an altogether new and patentable light-giving body is produced?"

I. Question No. 1. "*At the date of the Edison German Imperial Patent No.* 12,174, *was the use of a carbon thread* (*Kohlenfaden*) *in every form, novel?*"

1 *a. a.*—In regard to the word "novel" the patent 12273
law, part I., § 2, says:

"An invention is not considered novel, if, at the time of the application made according to the present law, it has already been described in public prints"—that is (cf. No. 234 of Dambach's Commentaries on the Patent Law) in prints introduced into the trade, made accessible to the buying public, exhibited or offered for sale in this or any other country, in no matter what language,—"in such a way, or has already been used in this country so 12274
openly, that thereafter the use of it by other experts seems possible."

1 *b. b.*—Concerning the word Kohlenfaden (carbon filament), there is a great danger to-day, that one will think of the fine, spring-like elastic carbon threads of the present incandescent lamps, which can be stretched almost straight and bent in wide limits without breaking, and start into vibration for a long time at every push against the lamp. These
cannot be meant by question No. 1. As the ques- 12275
tion is, whether the German Imperial Patent No. 12,174 is violated or not, only such carbon threads (Kohlenfäden) can be meant as are designated by the common usage of the language, or such as are described in this patent, or such as correspond with the notions of that time.

Therefore, for the decision of the preliminary question, which has to be decided first, namely, what is to be understood by "Kohlenfaden" (carbon
thread or filament), within the meaning of ques- 12276
tion 1, we have to consult above all the description of the patent. Next we have to investigate what in general could be understood by "Kohlenfaden" (according to the common usage of the language.

1 *c. c.*—The word "Faden" will be explained first *according to its meaning in the common usage of the language.*

The name Kohlenfaden (carbon filament), ex-

12277 presses only poorly the nature of the light-giving bodies of electric lamps. By a "faden" (thread) one understands, according to the common usage of the language, a body which is thin in proportion to its length, and which especially endures twistings and bendings to any extent desired, without *tearing.* A *faden* (*thread*) does not break nor split, but tears. It is not rigid nor inflexible in the least degree, but flexible, capable of being twisted at pleasure without being damaged. Its strength, if
12278 it possesses any strength at all, shows itself only in the direction of the length.

All these essential qualities of the "faden" (thread) *as the term is commonly understood*, the carbon thread of the incandescent lamps does not possess, and formerly it had them still less than recently. The carbon body of the incandescent lamps—and this is shown very distinctly by the older incandescent lamps Nos. 4* and 5, and by the lamps Nos. 1, 2 and 3 of the collection of lamps
12279 accompanying the records—was at first absolutely rigid and inflexible, and had about the elasticity of hard shellac. If you knock with your finger gently against these lamps, holding them in your hand, the light-giving body does not tremble nor vibrate. Therefore the light-giving bodies of the older lamps broke easily in transport, where they were exposed to violent shocks. Later on it was learned more and more—and the beginning was made by the light-giving bodies of Swan (G. I. P. No. 13,071,
12280 of the 29th of June 1880)—how to manufacture more elastic and more flexible light-giving bodies, which have the elasticity of fine glass threads or fine steel wires, but not the strength of the last named.

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* I have tried to characterize all the lamps accompanying the records by affixed labels (with my name), stating, after what patent the "faden" is made, and after what patent or how the *union* of the "faden" with the platinum wires is effected. For these statements I do not claim an absolute certainty.

The expression "Kohlenbüzel" (carbon loop), 12281
which for instance Edison uses in G. I. P. No. 23,129, or "Kohlendraht" (carbon wire), represents pretty well the nature of the light-giving body.

The expression "Kohlenfaden" (carbon thread) may partly have had its origin in the fact that both Edison and Swan made their light-giving bodies at first from real threads, namely from threads formed from the kneadable soft paste of lampblack and tar, or from parchmentized cotton threads.
But by the carbonization they lose the essential 12282
qualities of a thread and become similar to wires.

The diameter of an elongated body is, in many respects, no certain criterion of its being a thread or wire.

The transition from a thread to a stronger body, say a rope, is, it is true, judged pretty much alike by different persons. Different persons, before whom I laid the objects, called them "faden" (thread) from the finest silk-cocoon to a string or
wool thread of a diameter of from 2 to 3 milli- 12283
metres. From 4 millimetres upwards they all said rope or string. Short metallic bodies, some centimeters long, they called *wires*, up to a diameter of from 2 to 3 millimetres, and beyond that *rods, small rods, pieces* and the like.

Thus, according to the common usage of the language, the upper limit for the diameter of a thread or a short wire is at from 2 to 3 m/m. Carbon bodies are generally spoken of in the same
terms as long as the layman does not know the 12284
material. But as soon as he knows that he has carbon before him he does not longer use the expressions *thread* or *wire*, because ordinarily they are not used at all in speaking of carbon. According to the above, a carbon body of a length of several centimeters could be called a *wire* or (although less fittingly) a *thread*, if it has a diameter of 2 m/m or less.

12285 1 *d. d.*—The specification of the patent No. 12,174, in speaking of the English word *filament*, calls the light-giving body promiscuously "Faser" (fibre), "Faden" (thread) and "Draht" (wire), and thereby contributes not a little towards darkening the meaning. On page 476 and 477 of the English appendix to page 134 of the records, U. 905, 86, vol. II., the English judge, as an explanation of the word "filament" uses the words "very slender thread" (sehr duenner Faden), and as an English-
12286 man, whom we must think to be logical by virtue of his position, he might well be able to define correctly an English word by other English words.

The patent specification No. 12,174 speaks of the dimensions of the carbon thread or carbon wire in the following places:

Page 1, column 2, lines 11 to 13 from the top:

"Small pieces of this material can be rolled
12287 out into wires (Drähten) of a diameter of $\frac{1}{10}$ m/m and of a length of over 30 m/m."

Page 2, column 1, lines 3 and 4 from the top:

"By using a considerable length of carbon wire (Draht)."

Page 2, column 1, lines 19 and 20 from the top:

"Wires (Drähte) of different diameters and
12288 lengths."

The incandescent lamps accompanying the record, which I have marked Nos. 4 and 5, the light-giving bodies of which seem to be made after the G. I. P. No. 12,174, have carbon-wires of a length of 55 m/m and of a diameter of about 0.15 m/m.

Also the amount of the resistance, if stated in the patent, might be of importance for the meaning of the word Faden thread).

The term "high resistance" has been mentioned in different places all through the patent de-

scription of No. 12,174. But this expression being 12289
merely a qualitative one, cannot impart any definite clue to what amount of resistance in ohms is meant.

But on page 1, column 1, lines 32 to 36, it is mentioned that the inventor observed a resistance of from 100 to 500 ohms in a properly carbonized cotton thread, and furthermore (page 1, column 1, lines 38 to 44 from the top), that, if this thread is coiled into a spiral and carbonized, a resistance of 2000 ohms is obtained with a radiating surface of 12290
5 m/m, (should probably read 5 square m/m).

Although it is not said expressly, it seems, nevertheless, that Edison intends to use *such* resistances, that is of 100 ohms and more, in the incandescent lamps of Patent No. 12,174.

The lamps No. 4 and 5, accompanying the records, have a radiating surface of the light-giving body of from 20 to 25 square m/m.

Nor is the light-giving body coiled up into a close spiral (cf., p. 35 f.) in the meaning of the claim 12291
No. 2 of the G. I. P. 12,174, but the winding of the spiral are wide apart and therefore the spiral substantially radiates light outwards from its entire surface.

The resistance of the lamps No. 4 and 5 amounts, measured cold:

Lamp No. 4 (uncertain because of defects in the contact) to about 480 ohms;
Lamp No. 5, to 348 ohms. 12292

As experience teaches, the resistance during incandescence, which is the only one to be considered for incandescent lamps, amounts to about half the resistance measured cold; therefore,

Lamp No. 5, hot, about 174 ohms.

We have here before us, as it seems, light-giving bodies made from lampblack and tar, or the like, 12293 and by no means such made from ordinary unprepared carbonized carbon-threads or wood fibre.

A clue for determining the amount of the resistances referred to in the Patent 12,174 is perhaps offered by that of lamp 5, as soon as it can be proven that the light-giving bodies of this one are really made according to G. I. P. No. 12,174, and that the lamps Nos. 4 and 5 can be practically used, which is (cf., p. 72) very doubtful. The resistances 100 to 500 and of 2000 ohms, named for the carbon-
12294 ized cotton thread, are of no essential importance, because, as will be shown on p. 45, the use of carbonized cotton thread in an incandescent lamp cannot be patented at all by Patent No. 12,174, in default of a proper description.

The expression used on p. 1, column 1, lines 24 to 26 from the top, "current-conductors of carbon, having such a high resistance as to be suitable for giving light by incandescence," is without any quantitative meaning, since every first-class con-
12295 ductor of electricity, and carbon is such, no matter how great or small its resistance may be, can be rendered incandescent by the electric current and therefore suitable for light-giving, provided of course it endures the incandescence without changing its form.

D. R. P. (Deutsche Reichspatente—German-Empire Patent) No. 12,174, reads furthermore on p. 1, column 1, lines 4 to 6 from the top: "Which lamp offers high resistance and therefore allows of
12296 the practical subdivision of the electric light."

At the date of the D. R. P., No. 12,174, the object of the efforts of Edison and other technicists was the parallel arrangement of electric light-giving bodies in the circuit of the current.

This is evidently the meaning of "the practical subdivision of the light," although it is not said. But this does not give any clue as to the amount of the intended resistance. If to-day incandescent lamps of a resistance of 100 to 200 ohms are mostly used, this is due to the experience had in the last

five or six years. Resistances of from 100 to 200 12297
ohms are not considered absolutely the only ones to offer the possibility of the subdivision of the incandescent light. Incandescent lamps of 10, 30, 50 ohms (for instance, Bernstein lamps) have been successfully used for the subdivision of the incandescent light; they are burned partly in parallel, partly in a mixed arrangement, being placed both in series and in parallel. Furthermore, incandescent lamps of 1 and 2 ohms have been made recently for a series arrangement. 12298

Therefore the requirement of the possibility of the subdivision of the light would not offera positive clue as to the amount of the required sistance, even if the parallel arrangement had been mentioned in the D. R. P. No. 12,174, and so much the less as it is not mentioned. The success heretofore obtained in practice with the parallel arrangement of incandescent lamps of a resistance of from 200 to 300 ohms is not to be con- 12299
sidered at all in this interpretation of D. R. P. No. 12,174, for it was not in existence at the time of the date of the patent. The practical success of a patent cannot be considered at all in the interpretation of its text.

Thus, as has been explained under 1 *d d*, *in the patent specification No.* 12,174, there is *no positive clue* given *as to the amount* of *the resistance* of the light-giving bodies to be made. but *their diameter* 12300
is stated in the patent description to be $\frac{1}{10}$ m/m *and their length* 30 m/m, and the light-giving bodies of the lamps Nos. 4 and 5 accompanying the records have similar dimensions.

Furthermore, according to the common usage of the language (cf. p. 4 f.), such bodies also made of carbon which with a length of several centimeters have a diameter of not more than about 2 m/m, can be called "carbon thread," or, better, "carbon wire."

12301 1 *e. e.* The Royal Chamber Court has asked, under 1, whether *the use of a carbon thread generally* was new at the time of the date of D. R. P. No. 12,174.

Now in the present case the subject of the discussion is the use of a carbon thread (Kohlenfaden) for electric lighting, and especially—although the words glow-lamp, glow-light, or incandescent lamp which were almost universally used at the begin-
12302 ning of the decade, are not found at all, it is strange to say, in the whole patent No. 12,174,—undoubtedly the use for incandescent lighting in opposition to arc lighting. Considering the words of question No. 1, I shall discuss the novelty of the carbon thread (Kohlenfaden) in the art of electric-lighting in general, and at the end I shall answer the question especially with regard to the contents of patent No. 12,174.

12303 That at the date of D. R. P. No. 12,174 carbon threads—such as are meant in the widest sense, *sub.* 1 d., pages 4 to 8—"were already used so openly in this country that their use by other experts seems possible," has neither been known to me by my own experience (I add to this the remark that I have been especially interested in the progress of the application of electricity since the fall of 1878, and that I read a course of electrotechnics as early as 1882 at the University of Strassburg, which
12304 may have been the first course ever read in this department of learning), nor could I find in literature anything about public use in this country.

Regarding the publication of the invention of the carbon-thread in printed papers, I go back to the literature; I remark that all the publications referred to lie before me in their original.

Carbon, or, generally, light-giving bodies of high resistance, so far as I know, and so far as it has to be considered here, had been used for electric lighting prior to November 27, 1879, by

King, English Patent, 10,919............1845 12305
Roberts, " " 14,198............1852
Binks, " " 1,119...........1853
Ladyguine [Russia] (not accessible to me in the original)........................1872
Konn (Russia), English Patent.........1872
Harrison, English Patent, 3470...Sept. 2, 1878
Sawyer & Man, American Patent, 211,216. ....October 15, 1878
Von Choate, English Patent, 4388....... ....October 31, 1878 12306
Lane-Fox, English Patent, 4626...Nov. 14, 1878
Cheesebrough, English Patent, 4847..... .... Nov. 23, 1878
Pulvermacher, English Patent, No. 4774 ....November 23, 1878
Sawyer & Man, Scientific American...... ....Dec. 17, 1878, and March 8, 1879
Lane-Fox, English Patent, 1122....... ....March 30, 1879
Swan, Records, U. 905/86, Vol. II., page 126. 12307

King (1845) uses Carbon slips.

Roberts (1852) speaks of slips of graphite about 12 m/m long, 12 m/m wide, and as thin as possible, in a vacuum as perfect as possible, for incandescent lamps.

Binks (1853) takes a patent for rods or pencils for incandescent lamps, of charcoal, which he ob- 12308
tains through carbonization of brown coal. As insulators for metallic conductors he uses mixtures of lampblack and glue.

Ladyguine (1872), and also *Konn*, work with carbon rods for incandescent lamps.

Harrison (1878), makes flexible electrodes for arc-lights by enveloping silk thread and the like in carbon powder or other material. The same are not

12309 carbonized. The silk thread inside seems to serve only as a support of the formed carbon rope.

Sawyer & Man (1878), describe the preparation, which in the course of time has become extremely important, of thin rods from retort carbon, by means of glowing heat produced by an electric current in a hydro-carbon liquid, a process which to-day is used with almost all incandescent lamps.

Von Choate (1878). uses for electric light-giving
12310 bodies, a material "which is composed or formed "asbestos, mica, platinum, or *carbon*, or any com- "bination of them, and such other materials as "may be required to give the material the proper "affinity (Zähigkeit, Zusammenhang, Festigkeit, "Bindung—evidently glutinous substances are "meant) and homogenousness. These materials "(that would mean, for instance, carbon and glue), "are mixed and made to form a metallic or semi- "metallic material," (It must be noticed that car-
12311 bon belongs to the metallic conductors of electricity —perhaps, also Von Choate calls carbon semi-metallic material; at any rate, he names carbon and binding material, amongst others, as substances forming the material of the glowing body.) "which under "the influence of electricity becomes incandescent "and gives the illumination, which, however, prac- "tically speaking, does not volatilize, melt or flow "under the influence of the electric current."

"From this metallic or semi-metallic material,
12312 "preferably *wires* or bands of an appropriate size "are formed and shaped into arcs, *spirals*, or into "light-giving bodies of the shape of spiral balls," etc.

(The words enclosed in brackets are explanations on my part.)

Van Choate (1878), therefore, described amongst many other light-giving bodies quite evidently carbon Draht (filament or wire)—not at great length, it is true, but any how so that the idea can be fully understood.

Later on he speaks also of the burning of several 12313
light-giving bodies within one current circuit, *i. e.*, of the subdivision of the electric light, and of a means for making the brightness of the single lights independent from each other.

Lane-Fox (1878), describes at the start incandescent lamps with spirally coiled-up metal wires, or also with asbestos which is impregnated with carbon. Asbestos is fibrous material whose single parts have the size of thin yarn.

The light-giving bodies are completedly inclosed 12314
in exhausted glass vessels (application of the Sprengel mercurial air pump) or in glass vessels filled with neutral gas, into which platinum wires are inserted by fusion as conductors.

He describes further a so-called contact-incandescent light in the form of an incandescent lamp. This contact-incandescent lamp gives light without arcs—is, therefore, far from being an arc light—and by means of a specially bright incandes- 12315
ence of the light-giving body of a carbon at the end, where the same is evenly pressed against another larger piece of carbon. The light-giving body is a long pencil of carbon of a diameter of about 1.5 m/m., therefore, decidedly to be called a Kohlendraht (carbon wire).

The incandescence takes place as before explained in a glass vessel exhaused of air filled with neutral gas.

The conducting of the current is done by platinum 12316
wires inserted by fusion.

Cheesbrough, 1878. Takes an English patent substantially on the use of bars, pieces, or thin rods of carbon prepared after the mentioned process of Sawyer and Man, for incandescent lamps.

Pulvermacher, 1878. Will produce a pair of carbons for arc light in such a way that an interior thin carbon rod is spirally surrounded by a thinner carbon thread insulated from it. Both are made by

12317 pressing a mixture of pulverized charcoal or lamp-black and tar and pitch through a draw plate; after being formed, both carbons are packed in carbon powder and *baked* in a box. Although Pulvermacher calls the outer carbon also "a thread" (faden), the same must anyhow have had a diameter of at least several millimetres, in order to be serviceable as a carbon for arc light.

In the *Scientific American* of December 7th, 1878,
12318 a glow lamp with carbon pencil by Sawyer & Man is described, probably the one of patent 211,263; and *ibidem* March 8th, 1879, it is reported that *Sawyer and Man* make the light-giving bodies which they prepare in the above mentioned manner for use in the incandescent lamps, from willow branches, which are carbonized and are about 13 m/m long and 1.6 m/m thick. These willow branches certainly were not used as they are grown, but had to be peeled and to be reduced in
12319 their whole length to nearly the same cross section by scraping or splitting. So Sawyer and Man must be perfectly at liberty to split them also thread-thin, and then to use them for incandescent lamps.

With regard to this the Patent Office says in its opinion of February 8th, 1888 (see Record U. 903/86 Vol. II.), with perfect correctness:

> "Therefore everybody must be free to take willow branches of any thickness, also very thin ones, and nobody can be prevented from
> 12320 splitting such willow branches. In both ways one will obtain lamps with carbon loops of the thickness of linen or cotton threads."

Lane Fox (March 20th, 1878), says in regard to the resistance of the light-giving bodies of incandescent lamps, although not in regard to light-giving bodies from pure carbon:

> "Where an electro-motive power of 140 "volts is used in order to produce a light "about equal to the ordinary gas burner, "the light-giving part of the continuous con-

> "ductor, which I will call the *lighting bridge*, 12321
> "must have a resistance of about 300 "ohms or British Association units."

This statement of Lane-Fox answers with substantial correctness the practical conditions of to-day.

The light-giving bodies of Lane-Fox are pressed from a paste of graphite (graphite is substantially pure carbon) and an addition of poorly-conducting or non-conducting material—for instance magnesia,
zirconium, lime, "steatite"—under a heavy pres- 12322
sure, into solid pieces of the desired form, the greater or less resistance of which is obtained by a larger or smaller addition of the poorly-conducting materials. Besides this, the light-giving bodies are, as much as needed, covered with carbon by heating by the electric current in a thick hydro-carbon.

Swan (Records U, 905/86 Vol. II., page 126), exhibited in a lecture in Newcastle, on Feb. 4,
1879, an incandescent lamp with a carbon pencil 12323
of a diameter of hardly 1 m/m, and further in the spring of 1879 he purchased from Carré (consequently essentially of lampblack and tar), carbons in the shape of a hairpin. Whether these facts were *published*, in the meaning of the patent law, before November 27, 1879, I have not been able to learn.

12324

From the quoted literature it does not appear that already before November 27, 1879, an incandescent lamp with a carbon filament had been made which later on in the practice has given lasting satisfaction. But I add at once (cf., pp. 65–70), that also on the basis of the Edison patent 12,174 alone, such a lamp could hardly be constructed. At least the proof of the possibility of making such an incandescent lamp practically usable or commercially available, on the basis of patent 12,174 alone, 12325 has never been furnished by any party; for it is more than doubtful whether lamps 4 and 5 accompanying the record have these qualities (cf., page 11).

From the literature, especially from the publication of Van Choate (page), Lane-Fox, 1878 (p.), Sawyer and Man (page), it appears, however, that such light-giving bodies for incandescent lamps had been used before November 27, 1879, which according to the common usage of the lan-
12326 guage (cf., p.), and in the sense of question 1 presented to me, are to be styled as "carbon thread," or "carbon wire."

It is true that it seems doubtful whether in Van Choate's patent 4,388 the carbon wire is, as Sec. 20 of the patent law requires, so described that experts are able to make use of it; whether, therefore, this patent really excludes the novelty of carbon thread.

At any rate, Lane-Fox's description (English patent 4,626, 1878), Sawyer and Man description (pat-
12327 ent 211,262), answers the requisites of Sec. 20. And as, moreover, in the Scientific American it is said that willow branches are used for light-giving bodies, this also is sufficient. Any expert may carbonize them as thick or as thin as he pleases, according to the most ordinary rules, for instance, those of the charcoal-pile process. The manner of carbonization is in this case of little importance, for the preparation proper is made according to the exact directions of patent 211,262.

12328 Further, already previous to this, Lane-Fox had stated clearly that the light-giving bodies of incandescent lamps at a tension of 140 volts and with the brightness of ordinary gas flames (about 16 normal candles, to-day still the most used incandescent lamps) must have a resistance of 300 ohms. Lane-Fox expresses himself much more clearly than Edison does in patent 12,174. Of course the remark does not refer to light-giving bodies of pure carbon, but to such bodies of carbon with a larger or smaller addition of poorly conducting ingredients.

Moreover, on page 26 of the record, U. 729/85, Vol. 12329
I., Edison's attorney himself says in terms:

> "*The problem* which was to be solved, "i. e., *to make a lamp with a carbon conductor of very high resistance*, was known, "but nobody before Edison succeeded in "solving it practically in a satisfactory way."

I add, this problem can be solved on the basis of the Sawyer & Man patent 211,262 of the 2d of Oct., 1878, by the use of willow branches, with much greater prospect of success than on the basis of the 12330
D. R. P. (Deutsche Reichspatente) 12,174 (Conf., p.).

1 *f. f.* Referring to what is said under 1*a* to 1*e* inclusive, I answer, therefore, question 1, which runs in terms:

> "At the date of the Edison German-Empire patent No. 12,174 was the use of a carbon 12331
> thread (Kohlenfaden) in every form, novel?"
> —with No!

1 *g. g.* Had the question been put as follows:

Was the use of a carbon thread, such as under Sec. 20 of the Patent Law is described in D. R. P. 12,174, new at the date of D. R. P. 12,174;—then the question would be about a carbon thread of a carbonized mixture of lampblack and tar, with a diameter of $\frac{1}{10}$ m/m (Conf., page); and as such 12332
carbon threads of the size of $\frac{1}{10}$ m/m had not been used before Nov. 27, 1879, such a question would have had to be answered with "Yes."

12333 II. Question 2 reads:

> "*By patent No.* 12,174 *is the production of carbon threads (fäden), patented broadly and generally in such a way that every production of carbon threads without the permission of the owner of patent* 12,174 *is a violation of the patent?*"

2 *a. a.* The Patent Law prescribes in Sec. 20 that "the application [for a patent] must contain the "petition for the grant of the patent, and in the
12334 "petition must specify with precision the object "which is to be protected by the patent. In a separate document the invention is to be described "in such manner that thereafter the use of the invention on the part of other experts seems possible. Also the necessary drawings, illustrations "and samples are to be enclosed."

According to this the law requires a petition which specifies with exactness the object to be protected.
12335 It is true it does not designate this petition by the words "patent-claim"; however, in Dambach's Note 2 to Sec. 20 it is expressly said:

> "The application shall state with precision "the claim of the applicant for the patent in "a distinct petition-formula."

According to Sec. 20, the patent claims (as they are ordinary called) are the very patent itself. The patent description is expressly called a "supplement."
12336 The legal requisite of exactly defined patent claims has several times been questioned in the records, but it exists undoubtedly according to the sense of the law. The patent claims are binding as to the domain of the patent: the description serves to explain them.

2 *b. b.* Claim 1of patent No. 12,174 reads:

> "An electric lamp which gives light by in-

> "candescence and which consists substan- 12337
> "tially of a carbon fibre of high resistance "made and connected with the metallic "wires as described.

"An electric lamp which gives light by incandescence" cannot be protected by claim 1 as matter of course, as quite a number of such lamps were already known. It can be protected only *when it* "consists substantially of carbon fibre of high resistance, made and connected with the metallic wires
as described." 12338

Therefore, "carbon fibre, made and connected as described," forms the chief object of claim 1 of the patent, and *if such* carbon fibre forms the chief part of an electric incandescent lamp, then *also this lamp is protected* by claim 1. "Carbon fibre' with an article—let it be well understood; therefore, according to the common usage of the language, the designation of a substance without specification of the form constitutes the chief object of the first
patent claim. 12339

Should one here adhere rigidly to the text—and one is undoubtedly entitled to do so, for the law requires in the patent claim "*exact specification* of the object to be protected"—hardly anything would be left of the first patent claim, for the manufacture of "carbon fibre" fit for incandescent lamps is not described in the patent according to the requisites of Sec. 20 of the patent law (conf., p.). Under carbon fibre [Kolenfaser] one
can understand undoubtedly only carbon of a 12340
fibrous structure, *i. e.*, only such carbon as is made of natural fibres with preservation of their structure. "Artificial fibre" ["Künsliche Faser"] is not included. From a paste made of powder no man is able to produce a fibre; a thread from such material is granular, and not fibrous.

Thus considering the arguments on page 58 concerning the contents of the patent description, question 2 could be answered positively only with "No," for Claims 2 and 3 of D. R. P. [German

12341 Empire patent], 12,174, do not in themselves protect the carbon filament broadly.

However, with regard to the circumstance that the words of the patent "Kohlenfaden" [carbon thread], "Kohlendraht" [carbon wire], "Kohlenfaser" [carbon fiber], are all translations of the English "filament," which (conf., page 9) at any rate may be translated as "sehr dünner Faden" [a very thin thread], one may well be allowed to understand the expression "Kohlenfaser" [carbon
12342 fiber] of patent claim 1 as carbon thread [faden], or carbon wire [draht], by presuming that by the chance of the three synonymous translations just the one least favorable for the extent of claim 1 has crept into that claim.

Also, Edison himself says, D. R. P. 12,174, page 1, column 1, line 5 and 6 from the top:

"This carbon fibre (thus anyhow with the article and not as a mere specification of the substance) can be produced from a mixture of tar and lamp-
12343 black."

Considering, however, that the greatest imaginable clearness and unequivocalness is required by the law in the text of a patent claim, this interpretation of patent claim 1 is certainly a very liberal one.

12344

2 *c. c.* In claim 1 there would be protected in substance a carbon thread "which is made and connected with the metallic wires as described."

This relative sentence could be omitted just as well without the claim being thereby accorded a different extent. The patent law requires quite distinctly a description of the invention of such a kind that by it, that is, by the description, the use of it on the part of other experts appears possible. Therefore, what is not described in such a way, can

by no means be protected through a patent claim, 12345
although it has been named in the same.

2 *d. d.* Already from the answer to question 1 it follows, that carbon thread cannot be protected by D. R. P. 12,174 "broadly and generally," as neither the idea nor the manufacture of carbon thread in general was new on Nov. 27, 1879.

Besides this, again, the *patent description* shows 12346
this sufficiently.

(The following arguments will form also the necessary basis for the answers to questions 3 and 4.)

The text of the patent description 12,174 is exceptionally indistinct. Upon the reader it makes at once the impression of an overhurried document. So much is named and mentioned which is in no way described.

In the first 30 lines of the patent description is
the whole invention, and furthermore, erroneously 12347
in consequence of a mistake of the Patent Office, three instead of two chief parts of the same are at first set forth in general terms.

The *whole invention* is set forth in section 1. This also contains precisely the sense of *patent claim* 1, with the addition that the subdivision of the electric light shall really be possible by means of the invention. *How* the subdivision shall become possible, is not said, nor moreover is any de-
scription given. 12348

Section 2, (page 1, column 1, lines 7-14 from the top), names as *first part of the invention*, that which is protected in *claim* 2, namely carbon wire [Kohlendraht] or leaves, as light-giving bodies, which are "arranged in the form of coils or otherwise, so that a great resistance is opposed to the passage of the current, *and at the same time* only a small surface exists from which radiation can take place."

I have added the underlining in order to point

12349 out from the very start that section 2 requires a form of the carbon thread which, in the first place, gives high resistance—this is possible only when the thread is long and thin—and also requires the form of a coil or some other form which "at the same time," *i. e.*, while the thread is long and thin, results in a small radiating surface. Therefore, there is here described a form of the long and thin carbon thread and other forms, characterized sufficiently accordingly to Sec. 20 of the Patent Law,
12350 which present a small radiating surface. A common characteristic of all these forms is that the several parts of the carbon thread lie near to each other, so that one part prevents radiation from the adjoining parts. The adjoining parts radiate mutually upon each other on their adjacent surfaces, and these adjacent surfaces are therefore to be deducted from *the whole surface* of the long thin thread or leaf, in order to obtain *the radiating surface.*

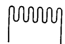
12351 To this end the adjacent parts of the thread must lie near each other, yet without touching, so as to allow the current to flow through all the parts in succession, and not to pass from one part to an adjacent part through points of contact. As the suitable form, the spiral or coil is here named, some kind of a spiral with windings lying close together, with a distance between the windings which certainly must not be materially larger than the thickness of the thread. In a very simple way the nature
12352 of the required form of the filament may be defined as such that, if one looks at the filament from different sides, in most of the eye's positions in relation to the filament, a part of the filament of considerable size in proportion to the whole length of the filament, must be hidden by parts of the filament lying before it.

The spirals or coils represented in the patent answer very well the requirements imposed upon the filaments as to form. The wide spirals of lamps 4 and 5 accompanying the record correspond to them

therefore in no respect. They emit light from their 12353
entire surface. The amount of heat which they impart to each other is quite imperceptibly small. Such open spirals are not at all meant D. R. P., 12,174, although the spiral is not, in every place where it is mentioned, repeatedly called close, or described with exactness as to its purpose.

There are quite a number of other forms besides those of the close spiral or coil, which answer more or less well the requisite conditions of the small radiating surface. 12354

The forms shown in the margin are some examples, which, however, are less convenient than the close cylindrical spiral illustrated in the patent. 12355



A hollow ball formed by narrow spiral windings, or hollow iron balls also belong there. They all are characterized by the necessity of the several parts of the long thin thread lying near to each other.

How great importance the patent ascribes to the 12356
form of this spiral or coil appears from its being named or described twelve times in the exceedingly short patent description.

In patent 12,174, moreover, in no place is another form besides the spiral named, much less described. On page 2, column 1, line 4 from the top, it is said:

"When the same (carbon thread) is coiled "so that only a small part of its surface "emits light, one can increase the specific

12357 "heat of the entire 'wire' [Draht], and in "this way prevent the sudden appearance or "sudden disappearance of the light, which is "disturbing in the straight wire, as with "the latter the smallest undulations in the "current manifest themselves by the flicker-"ing of the light."

Therefore, Edison sets out to use no straight wire and warns against it, because, if it be made as thin as Edison requires it, it has when raised to in-
12358 candescence too great a radiating surface in proportion to the amount of heat. This surface gives out heat at the same time with the light, and allows the thread to darken when the current slackens in its power; and so every undulation of the current is reproduced as a fluctuation of the light. Edison seeks to avoid this by the use of the spiral.

Edison's attorney lays it down that the clause, "when [*Wann*] the same is so coiled . . ."
12359 (Record U. 729/85, Vol. I, page 104), on account of the word "Wann," is a "hypothetical claim of the spiral." That is not so. By the context Edison excludes wholly the straight filament on account of its heat-radiating surface, and by the strict logic of this correct reasoning other forms also, horse shoes, open spirals and loops, having large cooling-off surfaces.

His thin filaments oblige Edison, on account of their rapid cooling off and of their flickering at the
12360 time of fluctuation of the current, to adopt forms in which long thin filaments can be so arranged that the radiating surface becomes small. At that time also all the lamps with noose-like threads or horse-shoe shape showed the flickering; they made the close spiral or the like decidedly desirable.

To-day, this flickering has disappeared in good lighting plants, because it has been learned how to avoid fluctuations in the current.

Accordingly, it is only the close spiral that is described, or other forms equivalent thereto as re-

gards the smallness of the surface of the filament 12361
(conf., page 37-8).

As *the shaping* here belongs especially to the manufacture of the filament, as the most important step in the manufacture, "the carbonization," takes place after the shaping, so the "made-as-described" carbon filament of claim 1 has unquestionably the form of a close spiral or other form (conf., p. 37) which will aid materially to reduce the radiating surfaces.

As *to the form, therefore, of the "made-as-de-* 12362
scribed" carbon filament, there is patented in patent claim 1 *of the D. R. P.* (German Empire Patent) 12,174, *besides the close spiral, only such forms as give a radiating surface small in proportion to the entire surface of "the long thin carbon filament." By no means is there patented as the form of the carbon filament the open spiral of Swan's loop or the horse-shoe* (*of lamps* 4 *and* 5 *accompanying the record*).

The arguments referring to this in the records, U. 12363
729/85, Vol. , page 38 and 39, and especially in section 2, page 39, *ibid*, are based on a complete misunderstanding of the purpose of the intended small radiating surface. I mention this because in section 2, page 39, *ibid*, special reference is made to the experts.

Also the respective arguments on pages 102-104 of the record, U. 729/85 Vol. I., are incorrect, as they too do not yet sharply apprehened the purpose of
the spiral. 12364

A seeming second division of invention is described in sections 3 and 4, page 1, column 1, lines 15-22. It refers evidently to the *proposed claim* relating to the vacuum lamp with platinum wires, which was stricken out by the German Patent Office. In the English patent (conf. records U. 729/85 Vol. I, page 301 and ff.) the affected patent claim has remained as claim 2. Why the German Patent Office has not, in connection with the affect-

12365 ed patent claim, cancelled also the description relating thereto in sections 3 and 4, cannot be satisfactorily understood. In fact in the specification a process of manufacture—namely, the mounting of the carbon filament in the vacuum lamp by means of platinum wires secured by fusion—is set down as *invention*, which is excluded as invention from the claims.

The *real second part of the invention*, (section 5, page 1, column 1, lines 23-30 and ff.) is covered
12366 substantially by *patent claim* 3. It mentions again, without any more detailed description, the carbon filament [Kohlenfaden] "of such high resistance that it can be used for giving-light by incandescence," and the connection of the same with the conducting wires

For question 2 it is without importance.

That the above interpretation of the whole inven-
12367 tion and of the two parts of the invention contained in the German Patent 12,174, is really correct, appears quite indisputably from the records U. 729/85 Vol. I. page 301 and ff. There we find Edison's application for the German patent, which, with the exception of larger portions cancelled by the German Patent Office and of a few alterations, agrees substantially with the D. R. P. 12,174. But we find there, at the first section of the description, as marginal notes marking the contents, the words:
12368 "I. Introduction. *a.* General Characterization."

I have characterized the contents of section 1 as "The whole invention." It is claimed as protected in claim 1.

At the beginning of section 2 we find in the patent application, in the margin, the words: "(*b.*) Special characterization of the parts of the invention," and this heading refers really to the mentioned five first sections of the patent description. Only then there follows in the patent application a new marginal note, namely:

II.—"Special part," in contrast to "I. Introduc- 12369
tion."

Unfortunately, the German Patent Office has cancelled these marginal notes of the patent application. Had they remained, they would have helped considerably to the easier understanding of the patentee himself.

Especially in the patent claim is *the whole invention protected, and in claims* 2 *and* 3 *the two subdivisions of the whole invention.*

12370

In other words, claims 2 *and* 3 *specify more exactly to what the "manufacture" and the "connection" in the patent claims refer.*

Now, in the patent application there follow two sections:

"II. A. A process used heretofore."

"II. B. Its disadvantages;"—

which are also cancelled by the Patent Office. They 12371
show in a striking way how little correctly Edison was informed as to the efforts made up to that time by other inventors, such as Sawyer and Man and Lane-Fox.

2 *e. e.* For the sake of brevity, I shall from this point on insert the marginal notes of the patent application, referring to the contents in brackets [ ], 12372
at the proper place in the opinion.

Moreover, page 1, col. 1. lines 31–41 *f.*, treats particularly of the use of a carbonized cotton thread as carbon filament.

[C. The new invention.
a. Discovery of the resistance and durability of the carbon filament (patent application)].

Of the treatment of the cotton thread nothing more is said except that it is "*properly carbonized.*" Of

12373 what kind the cotton thread shall be, compact or
loose; how the necessary uniform cross section is obtained;
how the carbonization is to be done, *i. e.*,
whether the thread in being carbonized is to be heated
quickly or slowly, about how high the temperature
shall be carried, how long it shall be kept up, how
the carbon thread shall be imbedded in the carbonizing
box in order to preserve its form; how the
carbonizing furnace is constructed, etc.—on all
these questions, which are very important for the
12374 good success of the carbonization, nothing is said
in D. R. P. 12,174.

But in his American patent which takes date
from Dec. 8th, 1879, for light-giving bodies from
carbonized paper, Edison prescribes, for instance,
that the bodies must first be heated quite gradually
up to 600 degrees, then to incandescence in the furnace,
and afterwards cool off slowly.

It suffices also merely to look at Edison's
important patent 18,887, of November 10th, 1880,
12375 in order to see how much Edison states and communicates
in a patent description as soon as he
knows it himself; and even here a good deal is still
omitted—for instance, the required degree of heat.
But in the application for patent 12,174 he himself
had not yet ascertained with certainty how a cotton
thread is to be carbonized "properly," *i. e.*, in
such manner as is required for the manufacture of
a practical burner for an incandescent lamp. Perhaps,
indeed, he had ascertained it, for he asserts
12376 that he had obtained such a filament, "which, even
at a very high temperature, remains absolutely unchanged."
But then, he ought also to have described it.

My conviction is, that he had not ascertained it,
and this conviction I have obtained particularly
from the statements of his collaborators in the
American lawsuit between Edison and Sawyer &
Man (Records, U. 729/85, Vol. II., page 19). The
original of these proceedings is not accessible to me.
From this statement, it appears that as late as Oct-

ober, 1879, Edison was fully engaged in experiments 12377
with materials of every possible description.

What Edison has said about the carbonization of
cotton thread, namely, that it must be "properly
carbonized," does not contain the least description,
nor anything in the slightest degree novel.

That a cotton thread could be carbonized was
known. But that expert who wants to carbonize it
according to the D. R. P. 12,174, must first himself 12378
invent the whole process of the carbonization; and
just the proper carbonization of such organic, loose
and fine structures is one of the most difficult processes
of carbonization. According to the records,
U. 729/85, Vol. I., page 482, even the factory, rich
in experience, of Siemens & Halske, which for several
years before had itself been manufacturing incandescent
lamps, was not able, even in the year
1887, to carbonize cotton thread so as to obtain a
commercially available lamp.
12379

From all this, it is evident that the treatment of
a cotton thread—and in like manner the raw material
spoken of on page 1, col. 1, line 40-42, as
"any fibrous vegetable substance which, after being
heated in a closed vessel, leaves a carbon residue—"
is not described according to the requirements
of Sec. 20 of the Patent Law. *Therefore,
the manufacture of carbon filaments for incandescent
lamps out of cotton threads is not to be considered
as protected by the D. R. P.* 12,174. 12380

Moreover, probably it was not without intention
that the Patent Office changed the expression of the
patent application "I have discovered" into "*Inventor
has observed*" (page 1, col. 1, line 31).

Without the marginal notes, "The New Invention,"
existing in Edison's patent application, the
cotton thread has continued to be mentioned in the
patent description of the D. R. P. 12,174, but is not

12381 protected by patent 12,174 (Conf. Record, U. 729/85, Vol. I., page 138).

On page 1, col. 1, line 46, to page 1, col. 2, line 4, there follows:

[*b*. Discovery of the possibility of varying the resistance. Patent application.] A short description of a process of changing the resistance of the filaments, which already Lane-Fox had given better.
12382 (conf., pages 23 and 24.)

Next there is described [*c*. Statement of a substitute for the carbon filament. Patent application], the manufacture of the filaments from lampblack and tar. (Page 1, col. 2, lines 5-25.) The description may be regarded as sufficient according to Sec. 20 of the Patent Law. Again, the form of the spool or spiral, just as on page 1, col. 1, lines 42–45—in relation to the thread of organic material—is empha-
12383 sized. Here, too, it is true, there is omitted again the statement of the temperature of the carbonization, but from page 2, column 1, lines 24–30, it follows at least that the temperature must remain below that of melting copper. In the carbonization of the compound of lampblack and tar, the question is only to carbonize the tar. For this the temperature of a moderate red heat is sufficient. In this vegetable cells cannot be destroyed through an improper management of the carbonization, because
12384 there are none existing.

If, therefore, according to custom, the filament is embedded in carbon powder, and is heated not too rapidly, with exclusion of the air, up to a moderate red heat, and is allowed to cool off slowly, one may, after some experiments, obtain useful filaments. It is a similarly simple process as when one burns porous clay vessels with an admixture of organic powders.

Although in the patent application Edison calls the carbon filament of lampblack and tar a "surrogat," it is nevertheless the only filament the mak-

ing of which can be regarded as described accord- 12385
ing to the requirements of Sec. 20 of the Patent Law. Now, on page 1, column 2, lines 20–25, it is said: "All these forms, however, are fragile and cannot " be clamped to the leading-wires with sufficient force " so that thereby good contact is secured and heat- " ing is prevented." By the latter test there is meant heating at the contact by reason of the resistance to the transmission of the current produced by bad contact. Thus all these forms are so fragile that they cannot with certainty be clamped to conduct- 12386
ing wires. Consequently, the carbon filaments the manufacture of which is described in D. R. P. 12,174, are emphatically not calculated to inspire confidence. Then, moreover, they can be easily broken by any push against the finished lamps. (Page 1, column 2, lines 26-40.)

[D. Discovery of the close contact, which is obtained by carbonizing the plastic material molded around the platinum wires. Patent application.] 12387

Because the carbon filaments made as described are too fragile to be attached to the platinum wires after carbonization, instruction is given to attach them to the platinum wires by plastic carbonizable material before the carbonization (conf., p. 86 ff.), and then to carbonize the whole. The description is clear and sufficient. It is to this beyond question that the last relative clause of claim 1 refers as well as the whole of claim 3. The metallic connection
through the walls of a closed glass vessel by means 12388
of fused-in platinum wires, was known to every expert long before November 27, 187?, and was openly practised at home in a thousand ways. This cannot by any means be the meaning of the last relative clause of claim 1, *the less so, as the German Patent Office has expressly cancelled* a special claim of the patent application covering the vacuum globe and *these platinum wires*. As further on no mention is made of any other connection of the carbon wire with the platinum wires,

12389 it may right here be *positively stated* that by the last relative sentence of patent claim 1, of the G. R. P. 12,174, which is "connected with the metallic wires in the manner described," *the patent protection of claim 1 is unmistakably limited to such carbon filaments* as have been connected with the platinum wires before their carbonization by molding around the ends of the platinum wires and of the carbon filaments when brought together (that is, without the application of clamps)
12390 a plastic mixture of lampblack and tar, and only then carbonizing the whole.

On page 1, column 1, line 41, to page 2, column 1, line 3—[F. Use of fine platinum wires as a connecting link. Patent application,]—the use of carbon filaments of high resistance is presented as the only possibility for using fine platinum wires. This statement is apt to make the practical value of the high resistance of the carbon filament appear exaggerated. But
12391 this is wrong. I myself have repeatedly conveyed into closed glass vessels stronger currents, such as carbon filaments of small resistance would require, by fusing into the wall of the vessel, as the path of the stronger current, a sufficient number of fine parallel platinum wires.

On page 2, column 1, lines 3–13 [G. Advantages of a closely coiled spiral. Patent application], the object which Edison had in view with the close spiral is clearly explained. (Conf., pages 35–41).
12392 It is to this arrangement that patent claim 2 refers. The close spiral, which here on every occasion and at each mention of a new filament material is again and again required, has never reached a practical industrial importance. (Conf., page 40.)

Page 2, col. 1, lines 14–23 [D. Special arrangement. a. Different kinds of material. Patent application]. Besides lampblack, graphite and carbon in different forms—of course not forms of the carbon filament, but of the graphite or carbon to be mixed; say, different sorts of graphite or carbon

pulverized finer or coarser—mixed with tar, are 12393
recommended as raw materials for incandescent bodies, cotton thread, linen thread, wood splints, paper, and again the coiling and rolling up of the filament is emphasized. For the here-mentioned organic raw materials—cotton thread, linen thread, wood splints, paper—considering the difficulties of their treatment, as has already been demonstrated at length on pages 45–49, description of their preparation ought to have been given, according to Sec. 20 of the patent law. This description is completely 12394
missing; consequently the use of these materials, "cotton thread, linen thread, wood splints, paper," is not protected by D. R. P. 12,174.

On page 2, column 1, line 24, to column 2, line 5, operations are described which are of interest for answering the question only in so far as here also the close spiral is emphasized again and again. The same is assumed to be so close that it is recommended, in order to avoid the contact of the adjoining spires, to wind up at the same time, before the 12395
carbonization, a copper wire for the separation of the spires (page 2, col. 1, lines 25, 26 and 27), or to cover the spires permanently and throughout with an insulating material.

(Page 2, column 1, line 43, to column 2, line 5.)

I remark, in passing, that in fact this last suggestion is hardly consistent with the manufacture of an available incandescent lamp. Quite evidently 12396
it has only been thought of, never executed.

On page 2, column 2, lines 6–26, the explanation of the illustrations follows. Only the close spiral is illustrated; and the sentence on pages 22 and 23, Fig. 2,—"shows the plastic material before "it is wound up into spiral form"—again says plainly, that the plastic material is always to be used wound up into a close spiral.

12397 *2 f f.* From all that precedes I draw the following conclusions: The patent D. R. P., 12,174, protects an electric lamp which gives light by incandescence, if it possesses one of the following characteristics stated under I., II., III.:

I. *If the carbon filament of the lamp is made from a mixture of lampblack, or carbon, or graphite, with tar, has a diameter of the size of* 1/10 *m/m., and has been brought into the definite form*
12398 *before the carbonization.* The giving of their form to filaments made of lampblack and tar, after carbonization, cannot be done at all, on account of the fragility of the carbonized product.

II. *If this form is the one of a close spiral, or other form which furnishes a small radiating surface in proportion to the whole surface of the thin filament.*

III. *If the filament before carbonization is con-*
12399 *necte:l with the platinum wires by means of a plastic, carbonizable material molded around the ends of the filament and of the platinum wires when brought together, and then carbonized around the place of contact at the same time with the filament.*

I is to be so understood that a thick filament of lampblack and tar is not protected, nor is there protected a filament of the diameter named which has
12400 been brought into definite shape before carbonization, but which is not made from lampblack, etc., and tar.

The characteristics I., II., III. are embodied in the patent claim. Characteristic II is protected more particularly in patent claim 2; and especially is there protected in patent claim 2 the form of the close spiral, *etc.*, for each carbon filament in an incandescent lamp That this protection for the new form of the close spiral *etc.*, can be obtained by patent, and does not fall under the law of protection for designs, is evident. It is not a matter of esthet-

ic design, but of the form of an industrial prod- 12401
uct, which would have become important for this industrial product, the incandescent lamp, if it had not not been learned how to obviate the fluctuations in the currents of the dynamo machine. It is not the known form of the close spiral, etc., that is protected absolutely, but the application of this form to the filaments of incandesent lamps with the expressed and well-defined purpose to make the *radiating* surface of these filaments small in proportion to the entire surface. 12402

Characteristic III. is also particularly protected by claim 3 *of the patent.*

2 g. g. In the records, U. 729, 85, Vol. I., pages 367, 386, the following decisions of the Reichsgericht (Imperial Court), have been quoted:

1. "The granting of a patent on a manufactured 12403
"article subject to the condition that the same "is made in a certain manner, is not admis- "sible."
2. "An opinion rendered in this regard by the Pat- "ent Office and the description and illustration "referred to in the patent are irrelevant as to "the contents to be attributed to the patent in "this direction."

"It contradicts the legal definition of a patent "granted on a manufactured article, that there- "by protection shall exist only in regard to such 12404
"articles as are manufactured by the particular "means invented by the patentee."

Respecting this decision the following observation is to be made: The article which is protected in claim 1 of patent 12,174 is not "an electric lamp which gives light by incandescence," without additional conditions; for such lamps were known in pretty large number. The claim, on the contrary, only protects such an incandescent lamp as contains a carbon fiber of great resistance, "made"

12405 and "connected" as described. But it protects the lamp with this finished carbon fiber, not, however, the process of making the carbon fibers.

But claim 1 does not, therefore, by any means, protect every carbon fiber, or every carbon thread. The carbon thread protected in connection with the lamp has very particular qualities. As a result of its origin it has a decidedly granular structure, which, when properly magnified, can easily be recognized, especially along a fracture of the filament.
12406 The binding material between the filament and the platinum wire has the same granular structure. The filament has but little elasticity, but is more crumbling, brittle and fragile. Although called carbon fibre (Kohlenfaser), it appears evident from the patent description, that it can by no means have a fibrous structure (conf., p. 31).

An incandescent lamp with *such* a filament, according to the quoted decision of the Reichsgericht (Imperial Court) is protected by claim 1
12407 even when the filament is made and connected otherwise than described in the patent.

I shall show (conf., page 73–78), that the finished filament made after patent 13,071, and connected after patent 19,851, has entirely different qualities.

It is partly fibrous, partly compact and hard, on the whole very elastic; also the union in the finished lamp is entirely different, even in its appearance, from the one made after the D. R. P. 12,174.

The filament of the Swan lamp (patents 13,071
12408 and 19,851) is, therefore, a different article from the filament of the Edison lamp patent 12,174. That it is an incomparably better product, is not the question here. The quoted decisions of the Imperial Court (Reichsgericht) have therefore no importance for our questions. They are now two different products, which are not alike, neither in structure nor in physical qualities, nor in form, consisting only of the same elementary substance, of carbon, and serving the same purpose.

The statement which appears occasionally in the

record, signifying that "an incandescent lamp is 12409
always an incandescent lamp," is very incorrect, for the patent-claim protects the incandescent lamp only when it contains the carbon filament described in the D. R. P. 12,174, with its characteristics.

2 *h. h.* The above thorough discussion of the patent 12,174 was necessary in order to be able to answer exhaustively questions 2, 3 and 4 of the Court.

On the basis of what has been said under 2 *a. a.* 12410
to 2 *h. h.*, pages 28–63, I answer, with view to determining the scope of the patent, pages 57–60, the question presented by the Court under No. 2,—

> "*By patent* 12,174 *is the manufacture of* "*carbon filaments patented broadly and gen-* "*erally in such way that every production of* "*carbon filaments without the permission of* "*the owner of patent* 12,174 *is a violation of* "*the patent?*"

With No! 12411

With regard to a possible objection on the lines of the argument on page 311 of the records, U. 729,85, Vol. 1, I add: "*Neither the manufacture of carbon filaments, nor the finished carbon filament as an article of manufacture, nor the incandescent lamp as an article of manufacture with the carbon filament, is patented broadly and generally by the D. R. P.* 12,174.

12412

III *a.*—Question 3.

"*In patent* 12,174 *is the manufacture of a carbon filament* [*Kohlenfaden*] *described in such manner that thereafter a carbon filament for an electric lamp of commercial availability can be manufactured by an expert without the aid of any other*

12413 *patents, especially of patents and inventions of a date later than the 27th of November*, 1879?"

So far as the question relates merely to the possibility of the manufacture of an incandescent lamp by an expert on the basis of D. R. P. 12,174, without the use of other patents, the question, in the light of the preceding explanations, is to be answered with—Yes.

12414 3 *b. b.* Only the *commercial availability* seems doubtful. Whether incandescent lamps which are constructed on the basis of patent 12,174 alone—*i. e*, which contain filaments from carbonized lampblack and tar—would be commercially available, cannot to-day be determined with certainty. The practice has had no opportunity to demonstrate this. If lamps of this kind have been manufactured at all—proof of this is not furnished—they have at any rate very soon been surpassed and replaced by
12415 other and better lamps—Swan's lamp, Edison's lamp with carbon loops made from paper, later on on with loops from bamboo fibre.

The allegation in the records, U. 721, 85, Vol. 1, page 38, where it is said, that a large district of the City of New York and several whole cities of America are illuminated with such lamps; that in all the great States of Europe, and especially in Germany, large stock companies have been formed exclusively for the purpose of manufacturing such
12416 lamps and of utilizing Edison's patents, particularly in Germany patent 12,174; that great factories, theatres and public localities are exclusively lighted with Edison's incandescent lamps, for instance in Munich the Royal Court Theatre and the club houses in the Schadow Street, *etc.*, is in part not proved, in part entirely erroneous, as all the allegations could be of importance only if made with reference to the contested Edison patent 12,174.

In Germany the patent 12,174 has never been

used at all in the commercial manufacture of incandescent lamps. By the mentioned "large stock companies," there can have been meant in the year 1885 only the then "German Edison Company," now the "General Electric Company." But the "German Edison Company" has never followed out even one single instruction of patent 12,174. Whether possibly they pay Edison a license fee for the use of the D. R. P. 12,174, is quite irrelevant. From the beginning they have made the carbon filaments according to patent 18,887, and the union of them with the platinum wires according to patent 23,129. I fully believe that I am correctly informed on this point; the present directors of the "General Electric Company" can give conclusive information about it. 12417 12418

The lamps used in Germany have, so far as I know and have seen, never been made according to patent 12,174, and for foreign countries every evidence in this respect is hitherto wanting.

I doubt the commercial availability of these lamps, especially on account of the great fragility of the carbon filaments made according to patent 12,174 out of lampblack and tar, and on account of the great difficulty of giving to the soft material in shaping the same cross section throughout. In letters patent 12,174, page 2, column 1, line 22 from the top, the uniform cross section is required, but it is in no way stated how it is to be produced. Lamps 4 and 5 accompanying the record reveal inequalities in the cross section of the filaments distinctly recognizable under a magnifying glass. But these inequalities, as experience teaches, quickly lead to the destruction of the lamps, as the filaments burn through at the thinnest place in consequence of an increased incandescence. 12419 12420

By an application to the filaments of patent 12,174 of the process which is protected in patent 211,262, one might perhaps obtain filaments of commercial availability.

As early as November 10, 1880, D. R. P. 18,887, 12421 page 1, col. 1, line 25–27, Edison himself abandons the carbon filament made of lampblack and tar, by saying, that only such carbon material as shows an actual structure (cellular formation, *etc.*), is fit for incandescent lamp filaments.

Accordingly I can answer *question* 3 of the Court only in the following way:

In patent 12,174, *the manufacture of the carbon filament out of a mixture of lampblack, graphite*
12422 *or carbon, with tar, is described in such a way that*
thereby a carbon filament for electric lamps could be made by an expert without the use of other patents—especially of patents and inventions subsequent to November 27, 1879.

Whether the carbon filaments made in such a way would be commercially available, only practical experience with such filaments, which hitherto,
12423 *so far as I know, is wanting, could determine.*

IV. Question 4.—

"*By the words 'purely carbonized' is there given "such a description as is required by Sec.* 20, *Art.* "1, *of the patent law?*"—

I answer, with reference to the explanations on
12424 page 45–49, with No!

V. *a. a.* Question 5 reads:

"*In Swan's improvement in the manufacture of "carbon loops for electric lamps, German Imperial "patent* 13,071, *is there effected by the use of a "thread of cotton yarn prepared by means of "parchmentization, such an innovation that thereby "every violation of the patent right secured by "the Edison patent* 12,174, (*patent claim* 1) *is excluded?*"

On the ground of the decisions of questions 2 and 12425
4, question 5 could without any further addition be answered with "Yes," since thereby (pages 45–49) it was proved that in D. R. P., 12,174 the use of a cotton thread for carbon loops, in default of an explanation of the preparation of the thread, is not patented at all.

With regard to possible further objections, however, and also because the nature of the parchmentization process has not so far been explained in de-
tail in the records, question 5 shall be entered upon 12426
more fully.

5 *b. b.* The carbonization of an unprepared cotton thread has so far not led to a serviceable carbon filament for incandescent lamps, because the single fibres of the raw cotton thread lie only loosely by the side of each other. Transversely, every cotton thread can easily be pulled apart without damaging the single fibres. If afterwards the fibres are again
laid together and the tightly stretched cotton 12427
thread is divided in the right direction, its former coherency is restored. The easy divisibility of the unprepared cotton thread reappears after carbonization as fragility. It can hardly be bent any more without a breaking of the now stiff, only mechanically intertwisted and intertwined fibres. I doubt, therefore, whether it be at all possible to produce a serviceable carbon filament for incandescent lamps from an unprepared cotton thread. Perhaps here
again the application to the carbonized thread, of 12428
the Sawyer and Man process, patent 211,262, might produce a serviceable carbon filament.

On the other hand, experience with the carbon filament made on the basis of Swan's D. R. P. 13,071 of June 29, 1880, has shown that very serviceable carbon filaments are obtained by immersing by Swan's method a thread of a suitable kind of cotton yarn or twist—crochet thread is especially recommended—in a bath of 2 parts of sulphuric acid and 1 part of water, and leaving it in there until a

12429 change—a condition of half solubility and thorough mixture—has taken place with the thread, similar to that which occurs with blotting paper in the well-known process of parchmentization. The thread is then at once carefully freed in water from the sulphuric acid mechanically sticking to it, dried and carbonized.

The words "condition of half solubility and thorough mixture" characterize somewhat the new condition of the parchmentized thread in regard to its
12430 mechanical qualities.

The process, so far as it has been studied heretofore, is the following:

The single cotton fibres (Freling's Manual of Chemistry, Vol. II., p. 459 & *f*; Vol. 1, p. 989), are broad cylinders with hollow canals pressed flat like a band and twisted likea screw. The surface of the cotton fibres is smooth and hard like wood. They consist in the main (except small percentages of other substances) of pure
12431 cellulose, the chemical formula of which, C_6 H_{10} O_5, signifies that the single molecule of cellulose consists of 6 atoms carbon, 10 atoms hydrogen and 5 atoms oxygen, or of a whole assemblage of this combination.

Now, Gerard (*Comptes Rendus*, Vol. 81, page 11,105, or also Wagner's Annual Report of Technology, year 22, 1876, page 1,066 and fol.), has found the following:

12432 If pure cotton is immersed long enough in cold sulphuric acid of 45 degrees Beaumé—this is the same as sulphuric acid of about 55 per cent., *i. e.*, a little weaker than Swan uses it—it is transformed through and through into hydro-cellulose of the chemical formula C_{12}, H_{22}, O_{11}. Every two cellulose molecules have chemically united with a water molecule—not, as might be imagined, mechanically absorbed, for they do not return it on drying—and a new chemical body comes into existence, called by others also amyloid. Now, under the

microscope the former cotton fibres appear much 12433
enlarged and stretched, and through the transformation into hydro-cellulose they have become extremely sticky, like thick gum.

Swan does not allow his threads to go that far. He immerses the cotton thread in dilute sulphuric acid, penetrating between the fibres only until by the effect of the sulphuric acid all the little fibres are transformed into hydrocellulose from
their surface down to a certain depth. The fibrils 12434
retain their form, only they swell, are transformed at the outside into sticky amyloid, remain inside cotton or cellulose, and retain thereby their firmness.

The whole thread swells together into a thick cord, the single fibres of which stick firmly to each other. The acid is removed in order not to act further, and the now dried thread is stiff but elastic, compact, hard like horn, has a fibrous structure,
and is exceedingly firm. Also in its appearance it 12435
has no longer a resemblance to cotton. It is smooth and transparent, and allows the fibrous structure and the twistings of the original thread to be recognized but slightly. It has quite the appearance of the thin gut-strings for string instruments (conf. the threads accompanying the records).

It is not cotton thread, therefore, that is carbonized, but the material which is carbonized is, in the the main, a dense mixture of cellulose and hydro-
cellulose of a partially fibrous structure, a new 12436
substance of changed chemical and physical qualities. Only the process of parchmentization makes out of the original cotton thread a body which is further transformed by the carbonization into a fine, hard, extremely elastic carbon filament having a slightly fibrous structure. To this filament (conf. records, U. 729/85, pages 160 and 169) the required form can be given after carbonization, which can be done neither with a carbon filament made according to D. R. P. 12,174, nor with a raw carbonized

12437 cotton thread. Both would break with any considerable bending.

The Swan carbon filament permits a notable facility of treatment in comparison with the filament of the patent 12,174, as it can be worked alone until finished, apart from the platinum wires. This is of importance, because the carbonization always produces a large percentage of waste-threads, which are useless. With the filaments of D. R. P. 12,174 the work of attaching the platinum wires had
12438 already before been performed with all these threads. Of the Swan threads only those are connected which, after carbonization, still appear usable.

The nature as well as the great value of the process of parchmentization, nay, its indispensability in the treatment of cotton threads for incandescent lamps, might be sufficiently evident from what has been said under 5 *b. b.*

On the basis of the above explanations, especially those under *5a* and *5b* (page 70 and f.), and refer-
12439 ring to the answers to questions 2 (page 64) and 4 (page 70), I answer question 5—

"*In Swan's improvement in the manufacture of carbon loops for electric lamps, D. R. P. 13,071, is there effected, by the use of a thread of cotton yarn prepared by means of parchmentization, such an innovation that thereby any violation of the patent right secured by the Edison Patent* 12,174 (*patent-claim*
12440 1) *is excluded?*"—

With Yes.

VI. a. Question 6:

"*Is the uniting of the carbon filament with the platinum wires after carbonization, as shown by*

the Gimmingham German-Empire Patent No. 19,851, 12441
as compared with a welding before carbonization (*Edison Patent* 12.174, *claim* 3), *something so novel that by reason thereof a violation of the Edison patent generally, and especially of claim* 3, *is excluded, and an altogether new and patentable light-giving body is produced?*"

6. *a. a.* The closing clause, "and an altogether new and patentable light-giving body is produced," leads me in the first place to make the
following remark in regard to the proposing of 12442
the question itself: If the carbon filament, which is attached to the platinum wires by the Gimmingham process, was not in itself a new patentable light-giving body—a filament, not violating D. R. P. 12,174 in the sense of question 2—it is also true, of course, that it cannot become so by the Gimmingham mode of attachment. Therefore the closing clause of question 6 can only concern the question: "If an incandescent body, new in itself, patentable,
and not violating D. R. P. 12,174, is attached to the 12443
platinum wires by means of the Gimmingham process, does this whole system, *i. e.*, the light-giving body thus connected with the platinum wires, become a novel light-giving body, and furthermore, does it violate the patent 12,174 through its connection with the platinum wires?" Only when it is allowed to be so understood is the meaning of the closing clause of question 6 comprehensible to me. Therefore, I shall answer the question with this interpre-
tation of the closing clause—*i. e.*, I shall not sup- 12444
pose that in comparison with the preceding contents of the question anything essentially new is meant to be asked by the closing clause.

6 *b. b.* In patent 19,851, patent-claim 1 (which is to be discussed here), reads thus (Records, U., 905/96, Vol. 1, page 21):

"The construction of a holder for the carbon
" filament out of two platinum wires, both of

12445 "which are flattened and bent, or, better,
"drawn up into tubular form, in order to re-
"ceive the extremities of the carbon fila-
"ment."

In this patent claim protection is sought only for
the construction of the carbon holders in the form
of platinum wires, bent together into tubular form,
into which the ends of the carbon are to be intro-
duced. To me, therefore, only the tubular form of
12446 the ends of the platinum wires and the introduction
of the carbon into the same, seem to be protected by
this patent-claim, and thereby by the whole patent,
but not the further process, set forth in the patent
description, of producing the sure contact between
the filament and the wires.

However, the question whether the Gimmingham
mode of attaching the carbon filament to the plati-
num wires is really protected in all its parts by
patent 19,851, is not of decisive importance for
12447 answering question 6.

I remark, in passing, that of the Swan lamps
which accompany the records, only lamps 14 and
15—and, more exactly the former probably, the lat-
ter certainly—have the form of the platinum wires
described and illustrated in D. R. P. 19.851, *i. e.*, of
little tubes with lengthwise slits. In all the other
Swan lamps accompanying the records, the tubule
is formed by coiling up the flattened end of the
platinum wire into a close spiral, so that thereby
12448 the opening runs spirally around the tubule.

6 *c. c.* The attachment process of D. R. P. 19,851
is the following: Gimmingham immerses the two
ends of the finished carbon filament, that is after its
carbonization, into a solution of platinum salt, and,
as he says, into a "carbonaceous substance, starch,
turpentine," that is, into substances which belong
to the class of organic carbonaceous compounds,
and which are decomposed by heating.

By high heat these bodies are decomposed into
carbonic acid and water, if air is permitted to enter.

When this is not the case, or the temperature is less 12449
high, carbon is deposited from them in their de-
composition.

The carbon ends thus prepared are introduced in-
to the previously described platinum coils, and the
whole is held for a moment over the Bunsen flame,
and thus quickly and gently heated.

With a strong heat there would be danger that
the carbon filament itself might be consumed. At
any rate the heat must not be raised to so high a
point; and thus the carbonaceous substances men- 12450
tioned are not burned up, but only decomposed,
and carbon deposited. Likewise, the platinum salt
on the carbon filament is decomposed and platinum
is deposited. Platinum and carbon are deposited
inside of the tubule between the latter and the car-
bon filament, and at various points a contact is es-
tablished between the two, especially where already
tubule and filament were fully or nearly in contact
with each other. But this imperfect contact is not
yet sufficient for a strong and positive connection 12451
of the two parts. Gimmingham now places at both
ends of the filament, very near to the point where
they issue from the tubule, a carbon clamp consist-
ing of two jaws, and causes an electric current, put
upon the two platinum wires, to pass only through
the smallest part of the carbon filament.

The current flows chiefly through the attached
carbon clamp which forms a short connection (of
small resistance) between these two ends of the car-
bon filament. 12452

The carbon filament is now immersed with the
platinum tubules into a liquid hydro-carbon; the
contact points are heated by an electric current, and
thereby, by a process well known and repeatedly
mentioned in this opinion, the hydro-carbon is de-
composed at the contacts between the platinum
tubules and the carbon filament, and carbon is de-
posited there, which alone renders the contact be-
tween the parts to be connected sure and firm.

12453 6 *d. d.* It is with this process that that of Edison must be compared. Patent claim 3 D. R. P. 12,174 reads:

> "The method above described of securing "the platinum contact-wires to the carbon "filament and carbonizing the whole in a "closed chamber, as has been explained."

On the manner of making the connection Edison expresses himself in the patent description D. R. P.
12454 12,174 in the following way (page 1, claim 2, lines 26–32):

> "When platinum wires are used and the "plastic material consisting of lampblack "and tar is molded around them in the act "of carbonization there is an intimate union "by contraction and pressure between the "carbon and the platinum, and almost perfect "contact is obtained."

Page 1, column 2, lines 37–40:

12455 "When fibrous material is used, the plastic "material of lampblack and tar is employed "to connect this material with the platinum "before the carbonization."

Page 2, col. 1, lines 27–31:

> "The ends of the carbon or filament are "attached to the platinum conducting wires "by means of a plastic carbonizable material, "and the whole put into a carbonizing "chamber."

12456

From these three descriptions, together with the preceding and following passages of the patent specification, it follows:

1.—That the joining of the carbon with the platinum wires takes place before the carbonization of the filament.

2.—That it consists in the molding of a mixture of lampblack and tar around the ends of the filament and the platinum wires, or also in the molding of the thickened end of the filament itself 12457
around the platinum wires.

3.—That finally the union is effected by the common carbonization of the filament and the binding materials into a sure contact for the electric current.

These are the three sole features of the method described in D. R. P. 12,174 of connecting the carbon filament with the platinum wires. From the reasoning under 6 c. (*pages* 81–86), *however, it* 12458
appears that the process of D. R. P. 19,851 *does not make use of any one of these features.*

With Gimmingham the connection is made after the carbonization of the filament. It is done by inserting the carbon filament, immersed into platinum salt and a carbonaceous organic mixture, into the ends of the platinum wires formed into little tubes, and by slightly heating the connections in an open Bunsen burner the union is completed into a firm contact 12459
by heating the temporary connection in a liquid hydro-carbon by means of the electric current.

Edison's and Gimmingham's methods of connection are therefore fundamentally different. It is true that with Edison, as with Gimmingham, the final connecting material is carbon. But in patent 12,174 it is not carbon as connecting material that has been patented, but *the method of attaching the platinum contact wires to the carbon filament.*

As to the binding material of lampblack and tar, 12460
it is alleged in the records, U. 722/85, Vol. I., page 95, with reference to the sentence beginning with the word "when," mentioned on page 86 as the second one (D. R. P. 12,174, page 1, column 2, line 26 and f.), that this binding material was mentioned only hypothetically or by way of example. The whole designated section of the D. R. P. 12,174 does not permit any doubt that this interpretation is erroneous. Besides, no other binding material and no other method of connection is named.

12461 Therefore, as to the question of the infringement of the patent by the form of union of D. R. P. 19,351, only the form of union described in the four sections of D. R. P. 12,174, quoted on pages 86 and 87, comes under consideration.

Referring to the arguments under 6 (pages 79-90) I therefore answer question 6:

"*Is the uniting of the carbon filament with*
"*the platinum wires after carbonization, as*
12462 "*shown by the Gimmingham D. R. P. 19,-*
"*851, as compared with a welding before*
"*carbonization (Edison Patent 12,174, claim*
"*3), something so novel that by reason there-*
"*of a violation of the Edison patent gener-*
"*ally, and especially of claim 3, is excluded,*
"*and an altogether new and patentable light-*
"*giving body is produced*"?—

With Yes!

12463

For the scope of a patent its practical importance does not come into consideration, as I have already mentioned before.

As, however, in many places in the record the practical importance of the contested D. R. P. 12,-174 of Edison has been asserted as a thing especially
12464 prominent, I cannot refrain from remarking in conclusion with regard to this importance as follows:

For the rapid development of the electric incandescent light in the years following the year 1879, the following patents have been of marked importance.

Sawyer & Man's American Patent No. 211,262 of October 15th, 1878.

Swan's American patent of January 2d, 1880, for exhaustion of incandescent lamps, whilst the carbon filament is glowing hot.

Swan's D. R. P. 13,071 of June 26th, 1880, for 12465
carbonization of parchmentized cotton thread.

Edison's D. R. P. 18,887 of November 10th, 1880, for carbonization of bamboo-filament, *etc.*

Edison's D. R. P. 23,129 for the galvanoplastic connection of the carbon filament with the platinum wires.

But of the methods and processes described in Edison's D. R. P. 12,174 none have become of essential importance for the electric incandescent light. 12466

In the above opinion I have thought to refer to the records only so far as their contents were of importance for answering the questions presented to me, or justified the presumption that from them
future objections might be raised against the con- 12467
tents of this opinion. It could not have been my task to refute singly all the erroneous assertions of the various documents of the record.

Hanover, October 30th, 1890.

(Signed.) Dr. Wm. Kohlrausch,
Professor of Electrotechnics
at the Royal University of Technology.

12468

12469 **Defendant's Exhibit Chandler's Testimony in the "Feeder & Main" Suit.**

[This Exhibit is composed of the following Questions and Answers:
Qs., 1-7; 9-11; 14.
Cross-Qs., 43-46; 94-99; 106-121.

12470 At the request of complainant's counsel the following additional parts of Prof. Chandler's deposition in the "Feeder & Main" suit are herewith printed in regular order—viz:

Qs. 8; 12; 13; 15; 17; 34; x-Qs. 38-42; 47-52; 55; 62-68; 72-4; 100-105; 122-5; 202-4; 245-7.

These parts, however, are not a portion of defendant's exhibit.]

12471

NEW YORK, Wednesday, November 5th, 1890,
2 P. M.

Met pursuant to

Present—FREDERIC H. BETTS, ESQ., for complainant; and S. B. EATON, ESQ., for complainant; and
12472 LEONARD E. CURTIS, ESQ., for defendant.

CHARLES F. CHANDLER, a witness produced on behalf of complaint, being duly sworn, deposes as follows:

EXAMINATION OF PROFESSOR CHARLES F. CHANDLER BY MR. BETTS:

1 Q. What is your name, age, residence and occupation?

A. Charles F. Chandler; age, 53; New York City; chemist by profession.

2 Q. Please state what attention, if any, you have given to the subject of electrical science and the 12473
practice with and use of electrical apparatus; whether you have been accustomed to give instruction upon the subject, and whether you have been engaged and acted as a scientific expert in any cases involving the consideration of electrical problems?

A. I studied the science of electricity at Gottengen under Weber, and at Berlin, chiefly under
Dove, in the years 1854, '55 and '56, and I have pur- 12474
sued the subject ever since. I have been for many years in the habit of giving a regular course of lectures every winter upon electricity. I have a large collection of apparatus and instruments which I use in illustrating these lectures, and I have been specially interested in all the practical applications of electricity. I have been in the habit of using the electric light for the illustration of my lectures, and I have a large and valuable collection of apparatus
to illustrate my lectures on electric lighting, includ- 12475
ing a small working plant of the Edison system. From time to time I have been called upon to investigate electrical questions, and I have frequently been called as an expert in suits relating to electrical patents. I was for several years engaged in experimenting in connection with a litigation with regard to the invention of Isaac Adams for nickel plating, and had occasion to study, experimentally, electro-metallurgy. I was employed to investigate
a new process for the manufacture of soda by the 12476
electrolytic decomposition of common salt. I was called as an expert in the electric soldering suit in connection with incandescent electric lamps. I have been engaged in testing storage batteries, and have also been employed as an expert in the storage battery suit of Brush against the Electrical Accumulator Company. I have also made investigations in connection with arc lights, and have been employed in telegraph and telephone cases. In general, I may say that I have had galvanic batteries and dynamos

12477 at my service, and have used them for various purposes whenever occasion required. I have been for the last twenty-six years, and am, at the present time, professor of chemistry in Columbia College.

3 Q. What connection have you had with corporations or other bodies engaged in distributing gas and water over large areas, and to what extent have you become familiar with the laws understood
12478 to govern the flow of ponderable fluids, such as gas and water?

A. For a long time I made a specialty of the manufacture of illuminating gas, providing myself with the most important literature on the subject and studying it carefully, visiting gas works in this country and Europe, writing and lecturing upon upon the subject. I am a member of the American Gaslight Association, and the New York Society of Gas Engineers; and I was at one time chemist to
12479 the New York Gas Light Company, resigning the position when I became president of the Board of Health. I have also paid a great deal of attention to the subject of water supply, having been frequently called upon by the public authorities of cities and towns and by water companies to give advice. Although my interest in both gas and water has been chiefly chemical and sanitary, I have, at the same time, become familiar with the principle involved in the distribution of these fluids, and I understand
12480 the same. I was at one time chemist to the Croton Aqueduct Department. In my study of natural philosophy, and in my study of gas and water supply, and my association with gas and water engineers, I have become familiar with the laws which govern the flow of ponderable fluids, such as gas and water.

4 Q. Have you examined any central station of elecric incandescent lighting plant, and do you understand the apparatus and methods used for dis-

tributing electricity over large areas for electric lighting? 12481

A. I have visited the Pearl street station of the Edison Company on several occasions since 1882, and I have also visited the Thirty-ninth street station of the same company. I have carefully examined all the appliances for producing and distributing electricity at these two stations; and I understand the apparatus and methods used for distributing electricity over large areas for electric lighting. I also procured from the Edison Company 12482
some time ago, for the purpose of illustrating my lectures on electric lighting, specimens of the conductors, junction boxes, &c., and had them put together in my museum, so as to illustrate the system of distribution.

5 Q. Have you read and do you understand the Letters Patent of the United States granted to the Edison Electric Light Company as assignee of Thomas A. Edison, dated September 19, 1882, 12483
No. 264,642?

A. I have read this patent, and I understand the same.

6 Q I notice in said patent the following statement:

> As is well known from patents already granted me, and prior applications pending, I use in my system an electric light formed of a continuous incandescing conductor. 12484

Please state whether you are familiar with the kind of electric light there referred to, and, if so, please state some of the general characteristics of such light, particularly with reference to fragility, capacity or incapacity for local regulation and the conditions which govern its effective life and illuminating power?

A. I am familiar with the electric light or lamp described in the patent; have large numbers of

12485 them and use them constantly, both for illumination and for other purposes. These lamps consist of a very delicate filament of carbon, often not much larger than a hair, and many inches in length. This filament is usually bent in the form of a loop, the ends being held by clamps or other devices, by which they are attached to wires. The loop is enclosed in a thin glass, balloon-shaped globe, from which the air is exhausted, the two wires passing hermetically through the glass. By means of the
12486 two wires the lamp may be connected with an electrical circuit in such a way that a current of electricity is made to pass through the carbon filament. Owing to the poor conducting power of carbon, or, as it is usually expressed, the high resistance of the filament, heat is developed, and the carbon becomes heated. If the electric current is so adjusted as to raise the carbon filament to a white heat, it becomes a brilliant source of light, and in this condition it constitutes the characteristic element of incandes-
12487 cent lighting. If the electric current is not properly adjusted the lamp will be practically useless. If the current is too low the temperature developed will not be sufficient to bring the carbon filament to a state of incandescence, and it will not produce light. If, on the other hand, the current is too strong, the delicate fibre of carbon will either be at once destroyed or it will be so disintegrated that it will be destroyed in a short time. If the current fluctuates in strength, then the action of the lamp
12488 will be very irregular. At one time it will give so little light as to be practically useless; at another time it will be so overheated as to cause either its immediate destruction or its rapid deterioration. When the current is properly adjusted the incandescent lamp is a constant, uniform and durable means for developing light, but the essential element in its management, both for efficiency and durability, is the regular and uniform supply of the electric current. There is no practical system of local regulation of the current to the individual

lamp. All that can be done at the lamp itself is to 12489
turn the current on or off. The current cannot be regulated in the same manner that gas can be regulated at a gas burner, by opening, at a greater or less degree, the stop-cock, nor is there any practical device, like a gas regulator, that can be attached to a single lamp or to the circuit within the house, as is done in the case of gas in order to regulate the supply. The successful use of the incandescent lamp involves the necessity of controlling the cur-
rent at a central station by means of a properly 12490
constructed circuit, where the management of the lamp is entirely beyond the control of the persons using it.

Adjourned to Saturday, November 8, 1890, at 11 A. M.

NEW YORK, December 3, 1890. 12491

Met pursuant to adjournment.

Present—Counsel as before.

EXAMINATION OF CHARLES F. CHANDLER CONTINUED:

7 Q. What was the problem in the art of electric lighting in and prior to 1880 necessary to be solved in order to render electric lighting with lamps of
low candle-power and in large numbers feasible and 12492
practicable?

A. There was no method known at that time by which large numbers of electric lights of low candle-power, giving about the same amount of light as ordinary gas-burners, could be established and operated over large areas in any feasible or practicable manner.

The problem was to devise a system of distribution by which the electric current necessary to operate the lamps could be sent to all parts of the dis-

12493 trict to be supplied at all times, in such volume, and under such pressure, as to cause the lamps to develop a useful amount of light.

At the same time the system must be so contrived that the current would never rise in intensity at any of the lamps so as to injure or destroy the lamp itself.

The system must be so arranged that the consumer would be able to turn on all the lights in his premises or to turn any or all of them off, without
12494 affecting the current of electricity so as to interfere with lamps left in use.

Further, the supply of electricity must be under such control at the point from which it is sent out that its pressure may be regulated and adjusted to the number of lamps in actual use at any given moment.

It must be possible to send the current economically under the conditions above specified great distances, and this must all be accomplished by a com-
12495 plete all-round system of metallic conductors (really of copper, as no other metal is suitable) of such moderate size and weight as to bring the cost within practicable commercial limits.

The system must also permit any desirable location of the lamps—that is, it must be possible to place some of them near the source of electricity, if it should prove desirable—while others might be located at a great distance, and the current of electricity would be so controlled that all the lamps, near
12496 and far, would be constantly supplied under all circumstances with the uniform current of proper intensity.

8 Q. Was this problem then, that is prior to 1880, regarded by electricians and scientific men as difficult or easy of solution? You may refer to the literature of the art and quote such statements on this subject as are now available to you?

A. Prior to the year 1880 this problem was re-

garded as extremely difficult, if not absolutely impossible of solution. 12497

Several of the most distinguished electricians and scientific men have put themselves on record on this subject.

In 1879 a committee of the British Parliament investigated the subject of electric lighting and published a voluminous report, which included the testimony of the experts who appeared.

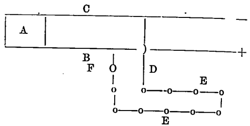
The following are some of the experts, with their opinions: 12498

1. Mr. Charles W. Siemens, Fellow of the Royal Society, Doctor of Civil Law at Oxford, a member of the Institute of Civil Engineers, and also a member of the firm of Siemens Brothers of London and Berlin. Mr. Siemens' idea of the method of electric distribution likely to be generally adopted in the future seems to have been a parallel series system, having a compensating device located in each branch circuit to keep the current practically constant. His admissions imply that these branch 12499
circuits should consist of as few lamps as possible; that for each lamp extinguished a corresponding resistance should be placed in the circuit; and that, generally speaking, each lamp would require as much electricity and cost as much when turned out as when in use.

The following sketch, which I personally make

12500

12501 upon the record, corresponds closely with his description:



12502

A is the generator of electricity.
B and C are the positive and negative mains.
D is the branch circuit.
F is the regulating or compensating device.
E, E are the lamps.

The following questions and answers are from the testimony of Mr. Siemens:

12503 220. Speaking of the question of the subdivision of the light, you said that there was no practical difficulty except the cost; supposing that we had ten lights in series, at work in different rooms, say, and a certain number of those lights were not required, there would have to be an outer position of equivalent resistance for each light put out; would not that be the case, supposing that the remaining lights were not to be increased?

A. Yes; that would be so.

12504 221. And, consequently, the lights which were put out would cost as much as though they were lighted?

A. That would be the case if several lights were put on the same electric circuit, but hitherto we have put central lights upon special circuits, and the putting out of a light would mean the breaking of a circuit or the stoppage of a machine.

222. But could that be practically done for domestic illumination; you would have your main conductor in the street; would you take

a special branch wire for each room off the main conductor? 12505

A. In making a large application of electric light it would be necessary to put a succession of lights upon the same circuit; but those would probably branch off a main conductor and each branch would be provided with a current regulation, so that each branch would work under all circumstances with a given amount of current. If the electromotive force of the current increased in consequence of a diminished resistance, through the stoppage of some of the branches, an extra resistance would have 12506
to be put into each branch circuit.

223. So that, in point of fact, a resistance equivalent to the action of the light is put in, whether it is burning or not, otherwise you have an increase of light in your other lights if they are on the same circuit?

A. There would be a certain amount of electric energy lost.

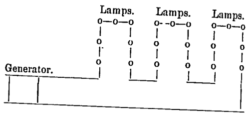
224. And therefore the cost is the same whether the light is burning or not?

A. Nearly the same.

12507

Mr. Conrad William Cooke, civil and consulting engineer, member of the Society of Telegraph Engineers and of the Physical Society of London, formerly a member of the firm of Whieldon & Cooke, electrical and general engineers, seems to think that subdivision of light was only practicable where economy was no object. His conception of practical distribution was undoubtedly a series circuit, in which an equal resistance must replace each light turned out, the expense to the producer being 12508
the same whether lights were turned on or not. He implied that he should believe that Mr. Edison had run two hundred lights on one circuit when he saw them burning. The following sketch, which I personally make on the record, embodies what he

12509 seems to admit to be his ideal method of distribution:

12510


He agrees with Dr. Siemens that centralization rather than distribution, should be the method adopted in electric lighting, and says subdivision "is the insuperable difficulty at present as regards domestic illumination."

He also mentions "parallel arc," and with reference thereto says:

12511 "When you attempt to subdivide the light beyond two or three, the intensity diminishes in a marvelous ratio."

And he is unquestionably in favor of the series in preference to the parallel method of subdivision. In this he undoubtedly referred to the arc lamp.

The following are some of his questions and answers:

388. Have you given attention to the question
12512 of obtaining light by means of incandescence, necessitating a closed circuit?

A. I cannot speak with any practical experience of that. My view of it is that you would have a far greater loss. It could not be done so economically, but it would probably be applicable in cases where economy was not so much an object, and where there was some special reason for dividing it.

389. Assuming a street to be worked on this method, the street to be joined up in series, and supposing the occupier of one house wished to put out his light, how would this be effected?

A. In that case, if you throw out a lamp, or

throw out a house, you must throw into the 12513
circuit a resistance exactly equal to what you cut out. If you do not do that, you will affect every lamp in the series and the machine as well. If you put out your lights by breaking the circuit, you put out every light in the series, and the engine will run away if it is not properly controlled; and if you put them out by simply short circuiting them, you will make the others brighten.

390. It would seem that the cost of a lamp working and one at rest would be the same, with the exception of the carbon which was not 12514
consumed?

A. The cost to the supplier would be the same, certainly. It would not affect the main current.

391 Q. Supposing that this were done, is there any means of learning the quantity of electricity which would be used in a given space of time by the occupier of a house?

A. I think that a contrivance might be made for the purpose, although it would be somewhat difficult to meet all the peculiar circumstances;
for instance, of a man shutting off the whole of 12515
his house, or shutting off one light, or shutting off two lights, and so on; you would probably have to have a meter at each light, I think in a case of that sort, because you must, if you shut off one light, put in an equal resistance. It might be done by shunting in a certain variable resistance at each lamp. In that case you could diminish your light due to the amount of leakage through the variable resistance. Certainly a meter would be a very complicated thing to arrange; you would have, I suppose,
to have some little electric motor. Then, again, 12516
I think it would be very difficult to arrange for variation in speed.

420 Q. Dr. Siemens, in his evidence, stated that the light could be centralized rather than subdivided; do you concur in that view?

A. That is what I meant.

421 Q. Is it not desirable that it should be subdivided?

A. It is very desirable for illuminating purposes that you should distribute your light in a great many places, but the moment you divide your current, at each point of division you

12517 lose a certain amount. In fact, you might at most compare it to changing money where you have to pay a commission at each change.

422 Q. I suppose that the fact that it cannot be subdivided is one of the difficulties in its practical use now?

A. That is one of the great difficulties in street illumination, and it is the insuperable difficulty at present as regards domestic illumination; but for the illumination of large halls and large areas I think that centralization is
12518 better than subdivision.

425 Q. Dr. Siemens, in referring to Mr. Edison, who is credited with having recently invented a machine for subdividing the light, expressed some doubt on the subject, and stated that he thought that it was not as promising as the reports indicated; do you know anything about that?

A. We really know very little at all about it. A few newspaper paragraphs have appeared on the subject, and I have been very much interested as everybody has. His nephew told me himself that he had seen, I think, over
12519 two hundred lights on one circuit. I must say that I should like to see it myself, and that is all that I can say.

Adjourned to Thursday, December 4th, 1890, at 11 A. M.

12520 Thursday, December 4th, 1890, 11 A. M.

Met pursuant to adjournment.

Present—Counsel as before.

Continuation of the answer of PROF. CHAS. F. CHANDLER to direct question No. 8:

WILLIAM HENRY PREECE, was called as a witness. He is the electrician to the Post-office.

510 Q. I think you have both considered and made experiments upon the subdivision of the

electric current for the production of various 12521
lights?

A. I have; I have examined the questions theoretically from a mathematical point of view and I have also examined it experimentally.

511 Q. Did you not publish a paper upon the subject in the January number of the Philosophical Magazine?

A. I did.

512 Q. What was the result that you came to?

A. In that paper I showed, first of all, that there are two ways of subdividing the light. Supposing that this piece of string which I 12522
hold in my hands were a wire conveying the current, we might insert in that one string several lamps, or we might take the several lamps and join them up in what is called a parallel arc. You may have your wires arranged parallel with each other, with one lamp in each. The result of my inquiry was to show that when lamps are joined up in series, the intensity of the light in each lamp diminishes with the square of the number inserted; and when they are joined up in this parallel arc, the intensity of the light diminishes as the cube of 12523
the number, showing, that when you attempt to subdivide the light beyond two or three, the intensity of the light diminishes in a marvellous ratio.

Mr. George Frederick Deacon, member of the Institute of Civil Engineers, of Mechanical Engineers, Borough Engineer and Inspector of Gas Lighting of Liverpool, and Electrical Assistant to Sir Wm. Thomson, in connection with the cable work of 1884 and 1885, during the Great Eastern Atlantic 12524
Cable Expedition, of 1865, assistant in the service of the Atlantic Telegraph Company.

Mr. Deacon stated that in all cases he had seen, with the exception of an arrangement of Mr. Werdermann's, lamps had been run in series.

He had heard that Mr. Edison also arranged lamps in parallel, but he had understood that Mr. Wedermann's experiments had demonstrated that his lamps would run to better effect in series. He thought that five or six

12525 lamps was as many as could be run economically on one circuit in series, and that possibly as many as that might be run in multiple arc; but beyond that number the cost would be too great by any system within his knowledge. He admitted that, if these lamps were placed one hundred yards apart, it would be necessary to place an engine and generator at each six hundred yards; he was, however, speaking in the light of practical results up to that time as he had the opinion of very high authorities for the belief that there were modes of overcoming the
12526 (then) present difficulties of subdivision.

He thought the electric light could not be applied economically to house lighting; and believed that in lighting houses by the series system the expense would be the same, whether the lights were burning or not; and that the multiple arc the light would be even less economical. He had heard reports of Mr. Edison's invention in connection with subdivision, but had not heard them substantiated; but thought they would ultimately be a very great increase
12527 in the efficiency of the subdivided system.

951 Q. At the present moment, in the illumination for public purposes, the lights are subdivided into series are they not?

A. Yes, in all cases, except one that I have seen. I believe that there is an American invention divided into multiple arc.

By Lord Lindsay: 952 Q. What system is that; the branch system?

A. No; I was speaking of Edison's.

By the Chairman: 953 Q. There have not been many experiments, have there, in the sub-
12528 division into parallel circuits?

A. The only ones that I have seen are those of Mr. Werdermann; and I understand now that his lamp has been used in series with better effect, but I have not seen it so used.

992 Q. Those lamps in the street, I suppose, would be in series, would they not?

A. I think that up to five or six lights on one circuit there is a possibility of division in series being accomplished with moderate economy; and it may be that division in multiple arc will also be carried to somewhere about the same extent. But, beyond that, I think either of them

will be so costly as to put a stop to much fur- 12529
ther division on any system which has yet been tried.

993 Q. Then, practically, it comes to this, that we can only use six lights in a series, and that would carry you over what distance of ground?

A. That depends upon the intensity of the light.

994 Q. If you put the lights one hundred yards apart, you can at the end of six hundred yards. You would require another engine and
another generator, would you not? 12530

A. Quite so. I am speaking entirely in the light of practical results up to this time. I know that certain mathematicians have attempted to show that it is impracticable to go further theoretically, but that is certainly not a universal opinion; there are very high authorities for the belief that there are modes of overcoming the present difficulties of subdivision.

998 Q. Have you considered at all the possibility of the electric light being applied to do-
mestic—that is to say, to chamber lighting in 12531
houses?

A. I think it is quite possible that it will be applied as a luxury; but, so far as I can see at present, again in the light of experience up to the present date, I do not think it is likely to be applied economically.

1001 Q. Supposing that you had your lamps in a house in series, how would you effect the reduction of a single light without affecting the others?

A. Theoretically there is no difficulty in do-
ing that as a matter of electricity; but, practi- 12532
cally, so far as I can see at the present time, I fear that the difficulty would be considerably greater than the mere turning of a stopcock, or regulating it by a stopcock.

1002 Q. You would interpose a resistance, in fact, would you not?

A. Yes.

1003 Q. And, therefore, that light would cost the same, whether it was burning or not, with the exception of the carbon?

A. Yes; with the exception of the carbons. That is, of course, in the case of lights in series

12533 only. But those inventors who have attempted to go further in subdivision, have placed their light in multiple arc and then other conditions come in which render it less economical on other accounts.

1029 Q. You referred just now to Mr. Edison; have you had your attention called to the more recently reported inventions of Mr. Edison, by which he claims to have subdivided the light so as to make it applicable for domestic purposes?

A. Yes, I have; but there appears to be a
12534 doubt whether those reports contain the last patents of Mr. Edison, upon which he bases his statements and his hopes.

1050 Q. With regard to the expense of the electric light, I suppose you would say that in a general way, all the tendency of modern improvements and investigation is to reduce that expense and to render the electric light cheaper?

A. I do not think that the concentrated lights will be very much reduced in cost, because I do not see where the diminution of cost
12535 is to come from. It cannot be in the machine, because we know that already a very high efficiency of the machine has been obtained. It can scarcely be to a very great extent in the lamp; but in the subdivision system I think there will be a very great increase of efficiency.

1061 Q. Have you any experience of the use of iridium?

A. I cannot say that I have any practical experience of the effect of iridium for incandescence.

1062 Q Is it not understood that most of Mr.
12536 Edison's patents and inventions have reference to the use of iridium?

A. An alloy of platinum and iridium, I understand.

1063 Q. Then, no one in this country is justified in expressing an opinion as to the possibility of dividing the light in opposition to Mr. Edison's statement, until it has been tried; is not that so?

A. No; but I think that if all that Mr. Edison had said, or rather all that has been said of Mr. Edison's inventions, had been literally correct, we should have heard a great deal more

about it now, because the time has passed when 12537
patents would have been secured.

1064 Q. Is it not the case that his last patent has only just been sealed?

A. I do not know how many patents there are. I have seen one or two of his French patents.

1065 Q. Are you aware that the "New York Herald" of last week (which I have this morning received from Mr. Edison himself) describes fully, with drawings, Mr. Edison's inventions for which patents have been recently taken out?

A. No; I have not seen it. 12538

Mr. Corbett Woodall, a member of the Institute of Civil Engineers, an engineer-in-chief to the Phœnix Gas Company in London, believed that it had been established that only a limited number of lights could be put on one circuit.

1163 Q. You spoke of the tendency which consumers of gas have to increase their consumption, and you foresaw in that fact a difficulty with regard to electric lighting; suppose
that would depend upon the power of the en- 12539
gine, would it not?

A. No; I take it that it has been established that only a limited number of lights can be put upon one circuit. If you want more lights it would be necessary either to bring a fresh supply into the house or to rearrange that circuit upon which you desired to put more lights.

Sir Wm. Thomson, LL.D., D. C. L., Professor of Natural Philosophy in the University of Glasgow,
president of the Royal Society of Edinburgh and 12540
Fellow of St. Peter's College, Cambridge.

Sir Wm. Thomson had an idea that lighting could be done in series and also in multiple arc, but had never worked the problem out, preferring to leave it to practical inventions to find out the best way; he thought, however, that the series plan would be the best way, provided a method was devised for preventing the whole of the lamps in circuit being extinguished when one lamp went out.

He could not answer the question as to

12541 whether private houses could be economically lighted by electricity, as there was so much to be done before it could be made practical; he, however, looked forward to the time when a block of houses would be lighted from the central engine, and thought it might be done economically and that a series system would probably be the best; thought it would not do to have many lamps in series on account of the necessarily high electro-motive force.

He believed that the short-circuiting of lamps
12542 to cut them out of circuit would be compensated for by inventions "yet to be made" which would provide in the machine a means for restricting the output of current to that required by the lamps left burning; this whether the lights were in the same or parallel circuits; he had, however, only thought of the matter in a general way.

1845 Q. So that my objection would, of course, not hold good if you had unconcentrated rays. With regard to street lights, supposing that you have a street lighted with a certain number
12543 of these high lights, would they be in series or in multiple arc, according to your suggestion?

A. I have not attempted to work that problem out. I see a way of doing it in series, and also ways of doing it in muliple arc. I would rather leave it to practical inventors to find out what was the best way. I have thought of the subject, but I have not thought of it as to its practicable bearing. I think that probably having the lights in series would be the best way with proper means of preventing the current from being stopped when any one of the lights accidentally goes out for a moment.

12544 1846 Q. Leaving that, and going to a domestic lighting, you said that you considered it possible, with advantage and economy, to light any rooms now in any houses, with the exception, say, of bedrooms, where small hand lights are required; would you also say that that should be done in series?

A. It would depend very much upon the mode of supply. I could scarcely answer that question, because there is so much to be done before it can really be made practicable; I think it would be too expensive at present for private houses ordinarily to have separate en-

gines for the electric light unless in a very large house. In large drawing rooms, perhaps, it 12545
might be advantageous even now. I look forward rather to the time when a block of houses may be lighted by a central engine; then I think it would be economical with only such electric lamps as we have at present, supposing that the lamps perfectly get over the difficulty about unsteadiness. I think probably series would be the best arrangement.

1847 Q. Then, supposing that we had a block of houses lighted from one station, the current will enter that house, pass through the differ- 12546
ent lamps in that house and go into the next house?

A. Yes; it would not do to have very many in series, because the electro-motive force would rise too high.

1848 Q. Supposing that we had a lamp in a dining room, and that after dinner I did not want that lamp any more, how should I put it out?

A. If there are other lamps in series you would do it by short circuiting it. It may be short circuited through a resistance, but then 12547
there would be a waste of light.

1849 Q. Then there is the same cost for that lamp as when it was burning, with the exception of the carbon?

A. Yes; but with proper regulators by inventions not yet made the machine will have a governor, according to which, when you short circuit without resistance any one of the lights, the machine will not give any more current than you want for the other light or lights, whether in the same circuit or in parallel circuits.

1850 Q. Such a machine as you mention is 12548
now being made, I believe, is it not?

A. I have not heard. I have scarcely thought of this subject myself, except in a very general way.

Mr. William Henry Michael, Q.C., F.C.S.

Mr. Michael looked upon the whole matter of storage, subdivision, continuous supply, and practical distribution over large areas as an hypothesis, in no instance demonstrated by fact or approximation.

12549 By Sir Lyon Playfair, Chairman: 2024 Q.
Is not that the fault of the investors; if in-
vestors are so imprudent as not to look after
their own interests, is that very much for the
Legislature to consider?
A. They always have considered it. It is
quite true that the maxim, *caveat emptor*, ought
to apply to all these transactions as well as
going into a shop and buying a yard of ribbon;
but we know that the public are uninformed on
all these financial questions. If it were, as you
12550 say, that the public are to protect themselves,
then you might say that all restrictions as to
the supply of gas or water should be removed.
But there is this cardinal difficulty to be got
over in this case; with respect to tramways,
you have occupied the street for once and all,
and there it is. In the present imperfect state
of our knowledge, you grant to-day to a com-
pany a *quasi*-monopoly for the supply of the
light. Next week, or next year, the whole of
the subject may be revolutionized; we may
then get some opportunity of knowing how to
12551 store up electricity, how to divide it and distri-
bute it, and how to get rid of those difficulties
which seem to a good many persons at the
present time to be insuperable. But in the
mean time you have tied up the public; you
have prevented their having the advantage of
that improved knowledge, for you have granted
a concession for twenty-one years.
2025 Q. I did not grant a concession, even
hypothetically, for twenty-one years; I spoke
of seven years. The time that it has taken to
develop the electric light to its present condi-
12552 tion has been sixty years; you would not sup-
pose that there would be such a tremendous re-
volution in two or three years. But would not
the argument cut the other way; that if you
give them no facilities under the Legislature at
all to open a public street, you are retarding
invention infinitely more?
A. I cannot see it. I have never yet seen a case
for opening up the streets by an electric company.
It is not, as it is in the supply of gas, where you
want an enormous main, which has to traverse
a very long distance. You have no evidence at
present that there is any possibility of storing
up electricity,

2026 Q. If there is not evidence as to the pos- 12553
sibility of storing it up, there is evidence that
you may have an engine working with perfect
steadiness, as you have the engines working the
ships crossing over the Atlantic for twelve days,
never ceasing a single revolution, and all that
time producing a steady outflow of electricity.
Is it not equivalent to storing up that your en-
gines are now so steady and so well made that
you can perfectly rely on their turning round
equably, and producing a vast amount of elec-
tricity, which would supply large districts?
A. Yes, but there is a fatal blot in the whole 12554
matter. I will follow your own hypothesis, be-
cause, in my view, it is simply an hypothesis.
You have got a perfect machine, and it is com-
petent to supply six houses with thirty lights
each; there are six houses in a row, and you
have some outbuilding or some place of that
kind from which you can send power to supply
the six houses, and there is a perfect light.
There comes, then, a time when the whole of
the lights are turned out except two, in two bed-
rooms; the engine must go on; you have no
stored up electricity; you must be making the 12555
180 lights in precisely the same way as if you
were only making two; and I fail to see how
you have established, with any information that
I have had, any analogy between that system
and the storing up of gas, which enables you to
lay down a main, and carry through it your
supply whether it is the smallest or the greatest
at identically the same expense.
2027 Q. The difficulty which you have men-
tioned just now did exist, and does exist to a
large extent; but the progress of invention is
so rapid that you will find that it will not prob- 12556
ably be many days more without being solved?
A. That will revolutionize the whole ques-
tion. The moment you are able to store up
electricity I acknowledge at once you have
entered on a new phase of the question.
2028 Q. Not storing it up, but economizing
its use; that was your point?
A. You have not quite followed me. I say
that, for supplying the two lights, your engine
must make the same number of revolutions;
must turn your expensive machine; you must
be incurring the whole of the expense, except

12557 merely that involved in the burning of the carbon point or iridium, or whatever it may be; putting that out of the question, the whole of your expense is precisely the same for two lights as for 180 lights. I say that that reduces the matter to an absurdity as compared with gas.

2029 Q. By Lord Lindsay: I was informed a few days ago that a patent is now being applied for which will answer your question?

12558 A. As soon as I see the specification for that, and see it in practical work, I shall admit that the time has come for legislation on the question.

Adjourned to Saturday, December 6th, 1890, at 11 A. M.

12559 December 6, 1890.

Met pursuant to adjournment.

Present—Counsel as before.

Continuation of the Answer of the Witness, Professor Charles F. Chandler, to the Eighth Question, continues:

Numerous other authorities have put themselves on record with regard to the practical impossibility
12560 of so subdividing the electric current as to make it available for use in large numbers of lamps, especially when these lamps are distributed over considerable area.

8. William Trant, in "Nature," republished in the "Scientific American" supplement, Number 158, January 11, 1879, discusses the divisibility of the electric light, and concludes his article in the following words:

"It will be seen, then, from what has been

above stated, that the production and divisibility of the light by incandescence is a very 12561
wasteful process; so wasteful, indeed, as to render its practical application impossible for general lighting.

"If, therefore, all Mr. Edison has to announce to the world is that he has succeeded in dividing an incandescent light, and the announcement that such is so is made on authority, his discovery amounts to very little. Both the light and its divisibility were discovered long ago. It will easily be seen that it is not in that direction that any great practical re- 12562
sults can be obtained. The voltaic arc supplies the only divisible light of any utility and economy, and it is in its development that any real progress must be looked for."

9. Professor Henry Morton, President of the Stevens Institute, and one of the most distinguished electrical authorities we have, wrote upon this subject to the editor of the "Sanitary Engineer," and was subsequently interviewed by a reporter of the "New York Times," who printed the results of the 12563
interview in that paper; he also delivered a lecture before the American Gaslight Association which was published in the "American Gaslight Journal."

The letter to the "Sanitary Engineer" was dated December 22, 1879, and is reproduced at page 379 of the defendant's record in this suit. The interview with the "New York Times" reporter was published in the issue of December 28, 1879, and is printed on pages 382, 383 and 384 of the defendant's record. The 12564
lecture delivered before the Gaslight Association" was printed in the "American Gaslight Journal of January 2 to February 17, and is referred to on page 385 of the defendant's record.

President Morton is evidently of the opinion that the practical subdivision of the electric current for the supply of large numbers of lamps is an unsolved problem, and one which is not likely to meet

12565 with solution. In his letter to the "Sanitary Engineer" he uses the following language:

> "I do not, of course, mean that Mr. Edison has not now, as he had a year ago, a lot of electric lamps running at Menlo Park, and that his year's work, starting out with the most confident assertion of an accomplished success, only awaiting granting of patents to be made public, has ended in landing him in an old method repeatedly tried and abandoned by others, and which this description (referring to the article
> 12566 in the "New York Herald" of December 21, 1879) furnishes no reason to believe has received any important improvement in Mr. Edison's hands."

In the interview with the reporter Professor Morton is alleged to have said:

> "The next difficulty is in the economical production of lights by electricity. This is what is commonly meant by the phrase, 'Dividing the electric light.' Up to the present time, and
> 12567 including Mr. Edison's latest experiments, it appears that this involves an immense loss of efficiency. Next comes the difficulty of distributing on any large scale the immense electric currents which would be needed, and to provide for their equal action at different points under varying conditions of the number of lights used."

In his lecture before the Gas Light Association, speaking of the Werdermann lamp, he says:

> "It will be noticed that here, as with all other
> 12568 lamps working by incandescence, there is a great loss, which increases with the subdivision. A gramme machine utilizing two-horse power should give with an ordinary lamp a light of from one thousand to fifteen hundred candles in place of the six hundred and forty here claimed from two lamps, or the four hundred candles claimed for ten lamps."

10. James N. Shoolbred, Member of the Institute of Civil Engineers, read a paper "On the Present State of Electric Lighting" before the British Association for the Advancement of Science, August

20, 1878, which is printed on page 706 of the Re- 12569
port for that year. He says that electric lighting has only attained to its present developement by certain marked stages of progress. His first stage begins with the production of the electric light at the beginning of the century, but the first real stage of practical application began with the production, in 1849, of large magneto-electric machines; the next stage began about 1867 with the invention of dynamo-electric machines; the third and present stage of electric lighting, he says, is that of the 12570
divisibility of the light—*i. e.*, the production of a number of lights from one machine—which he says has been accomplished by Lontin with his double-machine and the double-gramme feeding, the well-known Jablochkoff candles. He concludes his article with the following words:

> "Though electricity may replace gas lighting to some extent in the illumination of large areas and in certain manufactures, yet it cannot pretend to trench upon the special and the 12571
> most extensive field for the use of gas, the lighting of private houses, until some permanent, indestructible light producing points, very different from the present carbon sticks, be discovered."

11. Robert Briggs, Civil Engineer, published a paper on "The Absolute Economy of Electric Lighting" in the Journal of the Franklin Institute for September, 1880. The concluding paragraph of his paper as follows: 12572

> "The problem of electric lighting to-day is the production of small enough quantity of light with equal economy to that attained for large illuminating effects, and of the distribution into small sources of light of the great light capacity now obtained at a single point of emission. To these ends the intelligence of all electricians is now directed, and the attainment of some measure of success can be confidently anticipated."

12. W. H. Preece, Electrician to the General Post

12573 Office, &c., whose testimony before the Parliamentary Committee I have already referred to, published in "The London, Edinburgh and Dublin Philosophical Magazine" for January, 1879, an article on the electric light, in which he demonstrated mathematically the hopelessness of the experiments having in view the extensive division of the electric current for illuminating purposes. The following paragraph closes his article:

12574 "It is this partial success in multiplying the light that has led so many sanguine experimenters to anticipate the ultimate possibility of its extensive sub division; a possibility which this demonstration shows to be hopeless, and which experiment has proved to be fallacious."

13. J. W. Swan, one of the leading experimenters in connection with the development of electric lighting, delivered a lecture before the Literary and Philosophical Society of Newcastle-on-Tyne, October 20, 1880, which is printed in the supplement
12575 to the "Scientific American," numbers 264 and 265. Mr. Swan had himself invented an incandescent lamp, and in his lecture on electric lighting, here produced, he compares the arc light with the incandescent light, stating that the arc light is unsuitable for dwelling-houses and shops, and that it does not lend itself kindly to division or to extensive distribution. He thinks, however, that the incandescent lamp is available for these purposes, and proceeds to compare Mr. Edison's sug-
12576 gestions for distribution with his own. The following is quoted from his lecture:

"For supplying large towns with electric light Mr. Edison proposes to have a number of centres for the supply of electric power, perhaps a quarter of a mile apart, whence wires would be sent out in every direction, distributing the current to the houses round about. His plan of distribution is this: He proposes to send out bundles of main wires from each of the centres of supply, and from these main wires to branch as many small wires into the houses as there

are lamps to be lighted, each branch wire proceeding from a main wire to the place where 12577
the lamp is situated, and from thence to a return main wire.

"Now, although this plan has the great merit of simplicity, I do not think it will answer, except for very short distances.

"When a number of lamps are grouped together in that manner, it is necessary that the individual lamps should offer a very high resistance to the current, for if each lamp does not offer an extremely high resistance to the passage of the current there must be great 12578
waste, a large proportion of energy being in that case spent in heating the conducting wires, instead of the carbon in the lamps.

"Mr. Edison accordingly proposes to make his lamps of a very high resistance; he proposes to use for the incandescent material a form of carbon which offers a higher resistance than simple carbon in its compact state; but if carbon pure and simple, is used, then I submit, it had better be in as stable and condensed a state as possible, because in process of use it tends to consolidate, and it is 12579
undesirable that any change should take place in the lamp during use.

"The resistance offered by a filament of carbon in its best state for incandescent lamps, as thin as it is safe to use in a lamp, and of a length sufficient to give, say, a light equal to one burner, or ten standard candles (a unit of light, which, I think, we must not go beyond in planning an extensive system of town lighting) will not offer so high a resistance as that which Mr. Edison has made the basis of his scheme of distribution. 12580

"With lamps of this resistance, the result would be that before many were bridged across from one main wire to another, as much or more work would be done in the conducting wire as in the lamp. The only way of avoiding this waste of energy, without abandoning the idea of small units of light would be either to employ enormously thick conductors, or have a very limited area supplied from one works.

"I think the difficulty is capable of being surmounted in this way: Instead of grouping

12581 the lamps as Mr. Edison proposes, each lamp
being as it were a loop or bridge between two
mains, I propose to string them in series, 10,
50 or perhaps 100 lamps, being all interposed
in one and the same line. In this way every
lamp would add to the resistance of the line in-
stead of, as in Mr. Edison's plan, diminishing
its resistance. The waste of energy in the con-
ducting wire would thus be avoided.

"A copper wire, less than one-eighth of an
inch thick, would supply current for one such
12582 series of, say from 10 to 100 lamps, at five
miles distance, with a very small percentage of
loss; while to supply at the same distance a
corresponding series on Mr. Edison's plan
would demand copper conductors of such
thickness as would certainly make the plan
far too expensive, or, if such thick conductor
was not used, there would be an impracticably
extravagant waste of energy in the wire. If
even 50 per cent of the energy were expended in
the wire, the size of the conductor required to
transmit the current, say even two miles, would
be far too great.

12583 "There is no way of escape that I know of
from this dilemma, viz.: that either we must
make our unit of light larger than necessary
for a great many purposes, and so give up the
idea of extensive division and extensive distri-
bution, or, in order to gain these points, we
must group the lamps in the manner I have
proposed.

"There are, no doubt, difficulties in the carry-
ing out of my plan, but none that are not easily
surmounted. For example, if 20, 50 or 100
12584 lights were in a series, a break in any part of
the line would extinguish all the lights. This
danger can be met in two ways:

"I would have only one lamp belonging to a
given line in one house, so that the extinction
of such a line of lights as we are contemplating
would not be a very serious mishap; but I
would make such a mishap extremely unlikely
to occur by placing along with each lamp an
automatic circuit closer. This would so act as
to bridge over the gap made by the accidental
breaking or failure of a lamp, and so prevent
the extinction of the rest of the lamps in the
series, while a fresh lamp was put in the place

of the broken one—a thing no more difficult, 12585
and probably not more costly, than the replace-
ment of a broken gas chimney or globe.

"There is another difficulty occasioned by
the variation of the current in proportion to
the number of lamps in action.

"What is required in this case is to maintain
a uniform current in the line of lamps, whether
one or one hundred are alight. This can be
accomplished by self-acting apparatus some-
what on the principle of the governor of the
steam engine, and which would automatically
raise or lower the potential or pressure by steps 12586
of one-hundredths, according to the number of
lamps in use."

Mr. Swan read a paper on "Electric Lighting by
Incandescence" before the British Association for
Advancement of Science at the York Meeting in
1881, which is reproduced in the "Scientific Amer-
ican Supplement," No. 307 for that year, in which
he uses the following language."

"But the crowning merit of electric light pro- 12587
duced on the principle of incandescence is that
it is indefinitely divisible without sacrifice of
economy. You may have a lamp so construct-
ed as to give a light of ten candles, or you may
construct it with larger conductors so as to ob-
tain a light of 100 candles from your incandes-
cent carbon, and the smaller lamp will be
almost as economical as the larger—light for
light. That is, the ten-candle lamp will only
use one-tenth of the power, and, therefore,
cost one-tenth of the amount to maintain it
that is required by the lamp which gives ten 12588
times the light.

"This property of divisibility into as many
small centres of illumination as are required—
which is inherent to this method of electric
lighting by incandescence to fully the same
extent as in gaslight—combined with the steadi-
ness of this species of light, its good color, and
its wholesomeness, gives it a character of general
applicability which is not possessed by any
other kind of electric light. It is forty years
since Starr, through his agent, King, took out
his patent for producing light on this principle.

12589 It is only within the last two or three years that the many practical difficulties that beset the utilization of this method have been surmounted. Nothing can well be simpler than the ideal incandescent lamp. A slip of carbon in a vacuum, that is all. To realize this idea much experimentation had to be gone through and much disappointment to be suffered."

He closes his article with the following paragraph:

12590 "Now that we can look to the method of electric lighting by incandescence as a perfectly practicable method, and now that we have the means of combining the economy of the mechanical generation of electricity with the constancy and many conveniences of voltaic accumulation, it is clear that the time is now ripe for the almost unlimited application of electric light to general purposes, and that engineers may, with much advantage, give their immediate attention to the many details which fall
12591 within their province in connection with the mechanical production and distribution of electricity on a large scale."

14. C. M. Lungren published a paper on electric and gas illumination in the "Popular Science Monthly" for September, 1882, which was afterwards reproduced in "The Electrician" (London) for October 14 of the same year. Mr. Lungren says:

"The period of contest and denial over the
12592 question of the possibility of producing a light of low intensity by means of electricity that would be suitable for the general purposes of interior lighting has about drawn to a close. It is now pretty generally conceded—what there has never been any reason for denying—that the known laws of electric transmission interpose no bar to the successful solution of the problem, but that the difficulties in the way are solely of a practical kind. And it is further quite generally agreed that these practical difficulties have been for the most part resolved, and the question reduced down to one of cost supply; and, while a good deal of discussion

has taken place upon this point, but little has 12593
been written that will enable the general public to form a judgment upon the subject, and arrive at a trustworthy opinion of the relative cost of it and gas under actual commercial conditions."

* * * * * *

"The figures for the electric plant are based upon the work of Mr. Edison, as he is the only one who has so far made any attempt to put in an electric plant upon an industrial scale. And for that reason further only his system of distribution is considered, though it may be a ques- 12594
tion whether it is the one which will prove most satisfactory in practice."

15. F. J. Sprague, Ensign U. S. Navy, was detailed to make a report on matters relating to electric lighting, and spent some time in London for this purpose. He has published several papers, results of his observations. I quote the following paragraphs from a paper by him on The Edison System of Electric Distribution, 12595
printed in "The Electrician," for September 9, 1882.

"I do not propose to enter into any discussion as to the priority of the claims of this inventor as compared with any other, but to speak of Mr. Edison's system as it has appeared to me after a thorough investigation and study of the same, extending over several months, and with great facilities at my command; and my conclusions are based, not on Mr. Edison's 12596
claims or the claims of his friends, but are the result of a candid examination. Mr. Edison's ambition has been far-reaching, and he designs to establish a system of distribution, not alone for lighting, but for almost every purpose to which the electric current can be put, and he recognizes the all important principles that all parts of such a system are mutually dependent; that thorough mathematical and engineering talent must be used; that no detail is so unimportant, no real objection so trivial, but that it requires patient considera-

12597 tion; that dynamos, meters, lamps motors, conductors, districts laid out, capital invested and energy wasted, must all be calculated with reference to each other; in short, that economy and reliability are the great ends to be obtained. The result is, that he comes now before the world after three years of hard work and patient experimenting, feeling fully equipped and able to establish thoroughly reliable and extensive installations. I have stated some of the requirements of a system
12598 of general distribution, and will consider that with Mr. Edison in detail and as a whole.

* * * * * *

"At Holborn Viaduct there are, as many of you know, about 1100 to 1150 lamps furnished from the central station, distributed over a space extending from Holborn Circus to the Post-Office. The system of distribution here is that of multiple arc and branch circuits. Evidently, while simple circuits give perfectly satisfactory results in buildings and on the street for short distances, they will not
12599 do for large districts. And it is this question of distribution over large areas to which Mr. Edison has given a great deal of thought, and has, I think satisfactorily solved the problem.

* * * * * *

"Such is a brief résumé of Mr. Edison's system as it has appeared to me after long and thorough study—a system in the fullest sense of the word; one of supply, measurement and consumption; elaborate in detail, broad in conception. When we consider the present uses of electricity and the uses which will be
12600 developed when it is at every householder's command, we will be more able to appreciate the importance of Mr. Edison's work; and although there is improvement to be looked for I think he can feel satisfied that he has practically accomplished the work he set himself to do."

16. In the "Scientific American" for September 16, 1882, page 176, is an article on "General Incandescent Electric Lighting in New York," from which I quote the following:

"The great steam dynamos at the Central Sta-

tion of the First District were started in concert
on the afternoon of Monday, September 4th, 12601
and from that evening the new system of interior lighting has been one of the established institutions of the city. To a large extent gaslight has been supplanted through the district, and there is no reason for doubting the extension of the new lights to other districts as rapidly as the requisite central stations and systems of electric conductors, lamps, meters and other appliances can be produced. At any rate the new system has passed three of the four essential stages of progress toward commercial perma-
nence and success. When Mr. Edison first at- 12602
tacked the problem of incandescent electric lighting, he was met with the general objection of electrical authorities—that a durable incandescent electric lamp could not be made. When he proposed to subdivide the electric current, so as to multiply small lamps economically, he was warned on all sides that he was in pursuit of an impossibility; the thing could not be done. Having produced the desired lamp and subdivided the current experiment-
ally, his critics not less confidently asserted 12603
that a laboratory experiment was one thing, the practical application of a theory to a complex system of public service was quite another, and he was bound to fail. It was a question of economy; and, admitting that an incandescent electric lighting system could be furnished under the conditions required, it would not pay."

Adjourned to Monday, December 8, 2 P. M.

12604

12605 MONDAY, December 8, 1890, 2 P. M.

Met pursuant to adjournment.
Present—Counsel as before.

CONTINUATION OF THE ANSWER OF THE WITNESS, PROF. CHARLES F. CHANDLER, TO DIRECT QUESTION 8.

17. Dr. C. W. Siemens, F. R. S., gave an inaugural
12606 address before the Society of Arts, on November 15th, 1882, which is printed in "The Electrician" for November 18, 1882, beginning at page 17. Dr. Siemens stated that he thought it would be possible to establish electric mains in the shape of copper rods of great thickness, with branches diverging from them in all directions, though he was himself decidedly adverse to such a plan. He would limit the area of a densely populated district to one-quarter of a square mile, notwithstanding other individuals
12607 of high standing in electrical circuits held that areas of from one to four square miles could be worked to advantage.

With regard to the size of conductors, he said:

"In considering the proper size of conductor to be used in any given installation, two principal factors have to be taken into account: first, the charge for interest and depreciation on the unit cost of the conductor; and, secondly, the cost of the electrical energy lost through
12608 the resistance of a unit of length. The sum of these two, which may be regarded as the cost of conveyance of electricity, is clearly least, as Sir William Thomson pointed out some time ago, when the two components are equal. This, then, is the principle on which the size of a conductor should be determined."

* * * * * *

"The proper size of conductor to use for installation of the magnitude I have supposed would be one 48.29 inches section, or a round rod eight inches diameter."

* * * * * *

"It must, indeed, be admitted that the transmission of electrical energy of such potential 12609
(200 volts) as is admissible in private dwellings would involve conductors of impractical dimensions:"

18. Frank J. Sprague, Ensign United States Navy, made a report to the Navy Department on the exhibits at the Crystal Palace Electrical Exhibition of 1882. This report was published at Washington in 1883. Mr. Sprague takes up the different incandescent lamps exhibited at the Crystal Palace 12610
and describes them, and I quote the following remarks with regard to a few of them.

THE LANE-FOX LAMP.

"At the Crystal Palace the multiple arc system was adopted. About 300 to 400 lamps were supplied by Brush dynamos of the Sellon-Volckmar accumulators. Some were in independent circuits, and two or three machines were also joined in parallel circuit to supply a number of lamps. The effect in the Alhambra Court, 12611
supplied by the dynamo machines, and in well-furnished rooms where the accumulators were used, was very fine. The arrangement of the latter was good, but looking at that of the lamps and dynamos as a system, it was sadly deficient. In fact it was not a system, for the simple coupling together of a machine which will give a current of electricity to a maze of wires, and of lamps which are kept at a state of incandescence by the passage through them of a current, without regard to safety, economy and reliability, cannot be properly so dignified. I will not 12612
enter into any detailed criticism, for I scarcely think it necessary. As a test of the quality of manufacture, the current was reduced by lowering the speed of the dynamos until the incandescence was just generally apparent. The degree of redness was very uneven, and the test by no means satisfactory."

"Mr. Lane-Fox has not only invented some incandescent lamps, but he has proposed one or two systems for the distribution of light, heat and power by means of electricity."

* * * * * *

12613 "One set of mains, C C^1, is used, to which are coupled the like poles of the dynamos, A A A. The mains, submains and branches, C^{11} C^{11}, ramify in various directions, supplying the lamps directly, or accumulators, S, which in turn feed the lamps. Each house and the dynamos are connected to earth by earth conductors and plates, E E E, making thus one system of conductors answer the purpose of distribution.

"It is proposed to maintain the differences of
12614 potential at one hundred volts, and to do this by a regulator, R. of ingenious design, in which a shunted current controls a lever armature playing between contact pins, which, by its movement, one way or other, throws resistance into or out of the field magnet circuit, F. F. The current supplied either to lamps or accumulators is to be measured by one of several kinds of motor-meters devised.

"I cannot express my approval of this arrangement. A system of domestic lighting which proposes the use of earth conductors, with all the known attendant perils and incon-
12615 veniences, cannot be too severely condemned as lacking in every real essential of practicability or efficiency, economy or reliability, and of the commonest safety."

The British Lamp.

"At the Crystal Palace the lamps were generally, if not always, coupled in multiple arc, and the current was supplied by Gramme dynamo machines. The fix-
12616 tures were used as a part of the return circuit; but this is a most objectionable feature, and in any general distribution cannot be tolerated. The whole arrangement, although showy, was not a good specimen of electrical engineering. No plan of a real systen was shown. As a test of the quality of the manufacture, the dynamo speed was lowered till the lights were at a low incandescence. They stood the test much better than the Lane-Fox lamps, but quite a number of variations were noticed."

The Gatehouse Lamp. 12617

"This inventor proposes to combine platinum and carbon to make a lamp which will not break, or change incandescence materially, when the main potential changes. The resistance of platinum increases with heat, that of carbon is diminished. Two methods are proposed of utilizing these opposite qualities. One is by shunting a platinum wire with a carbon loop, one or both being in a vacuum; as the potential at the lamp terminals increases, an increased current flows over both paths; but 12618
because of the opposite changes in resistance the greater part of the increased current flows over the carbon path, at least, so it is claimed. This carbon may or may not be in sight. A second method is to prolong the platinum connections at the ends of the carbon filament into spirals, to introduce into the circuit a resistance which increases with an increase of current. The most that can be said of any such combination is that it is ingenious, hardly that. In the first place, in any properly designated system there will be no great change of 12619
potential. Then again, to constantly throw energy, in view of a most improbable and entirely unnecessary fluctuation of potentials, is very poor economy. In short, the lamp as designed shows a lack of comprehension of the demands of incandescent lighting."

The Maxim Lamp.

"The lamps can be run at as high, if not higher, power than any other made. If the exhaust were made at the neck instead of at the top of 12620
the globe it would be better. The normal power of the lamp is 20 candles, and the resistance is 44 ohms, which is too small for any widespread distribution.

"At the Crystal Palace there were 100 to 150 lamps, about 100 being maintained. These were supplied by a Maxim dynamo, the field magnets of which were excited by a second machine with movable commutator brushes. The lamps were run in a multiple arc system, with two lamps as a unit.

12621 "The Maxim plan of distribution, whether with one or more lamps for units, is that of simple multiple arc of main and derived circuits. * * * No meters or general arrangement for distribution were shown."

THE SWAN LAMP.

"At the Crystal Palace there were two or three hundred lamps in very satisfactory operation, the majority being run by a Siemens
12622 alternate current machine, separately excited. * * * Mr. Swan's lamps, much of whose excellence is due to Messrs. Stearne and Gillingham, are used on all sorts of machines, in all sorts of combinations of series and multiple arc. No particular system is insisted upon, nor are the lamps made comparable with any standard of resistance when of different powers. That is, the production of a good lamp is looked upon as the great desideratum and it is not an integral part of a system designed as a whole. As I have said, the tendency is tow-
12623 ards lamps of high resistance, but as to Mr. Swan's idea of a system, I quote from his address to the Literary and Philosophical Society of Newcastle.

(Quotation from Mr. Swan:)

"'As it is only necessary, in order to maintain a given current, to increase the force which produces it in the same proportion as you increase the resist-
12624 ance to its flow, it follows that the cost of raising to a certain degree of incandescence a longer or shorter length of carbon or of maintaining a ten-candle light or 100-candle light, will be exactly proportional to the light produced. If you have an electro-motive force sufficient to drive such a current through 100 inches of my carbon filament as will render it incandescent, you may either have the 100 inches in one continuous length all in one lamp or you may cut up the 100 inches into 100 pieces and place each piece in a separate lamp, and the 100 lamps in 100 different places, without any difference in the aggregate amount of light

from the one undivided light and from the 100 12625
separate lights. You may even contemplate on this principle the economical production of an electric light as small as a rush light.

"Speaking of the multiple arc system, he says that it has the advantge of simplicity, but does not think it will answer for other than very short distances."

Mr. Sprague then quotes further from the address of Mr Swan, but, as I have already quoted it in my 12626
No. 13, I will not repeat the quotation. Mr. Sprague then continues:

"This address was delivered in October, 1880, and in May, 1882, the revised copy was officially issued to myself and others; hence at this latter date it is reasonable to suppose Mr. Swan's opinions had not been changed. In August, at the meeting of the British Association, in some remarks after a paper I had read on the Edison system, Mr. Swan, amongst other things, said: 12627

(Quotation from Mr. Swan:)

"'The only escape from that limitation (extent of distribution) lay in having secondary batteries at stations or in houses, and in these batteries being connected in series and fed by currents of higher tension; the principal still holding of multiple arc, not from the central station, but from the subsidiary ones at which the batteries are charged. Once imagine the possibility of these secondary batteries being kept at a per- 12628
fectly constant condition of charge by some automatic arrangement, and we might look to that as a means of escaping from the difficulties of wide distribution.'

"He did not give up the idea of supplying the lamps entirely in series."

(Quotation from Mr. Swan:)

"'It would only be necessary that each lamp

12629 should be provided with an automatic arrangement for maintaining continuity of circuit. * * * The only condition necessary would be the maintenance of the lamp in a condition of equality of light, that the current should be kept constant, and that there should be automatic arrangement for varying the electro-motive force at the station in proportion to the number of lamps operating, whether 1 or 1,000. To avoid the use of a high potential in such a system of feeding-in series, the resistance might be very considerably reduced by variation of
12630 the internal sectional area of the carbon by making short and flat carbons.' "

Adjourned until 1:30 to-morrow, Tuesday, December 9, 1890.

NEW YORK, December 9, 1890,
12631 1.30 P. M.

Met pursuant to adjournment.

Present—Counsel as before.

CONTINUATION OF THE ANSWER OF THE WITNESS, PROF. CHARLES F. CHANDLER, TO DIRECT QUESTION 8:

The witness continues the quotation from Mr. Sprague's report on the Crystal Palace Electrical
12632 Exhibition of 1882.

"More than two years have passed since the Newcastle address (of Mr. Swan). The Swan lamp has reached a point of high perfection; yet we see no large system of lamps arranged in series, and the many practical difficulties foreseen by the inventor and by others still await solution. Had it not been for his recent utterances, and for the fact that the lamp is still used in multiple series combination, I should look upon the subject as practically abandoned, and the place taken either by the multiple arc direct supply, or multiple arc from central ac-

cumulator stations. I am not yet converted to 12633
the faith of accumulators in private houses.

"The plan proposed by Mr. Swan of having several subsidiary central stations of accumulators which derive their charge from a distant station, supplying currents of high tension, is a thoroughly practicable one; but accumulators must be first much improved, both in regard to space occupied and economy of conversion, and in this case I still claim the necessity of the absolute multiple arc system for both streets and houses in a sub-district. That is, the accumulators would simply take the place of the 12634
dynamos and engines, they being charged by these last, or by high tension currents from a distant station. Which method would be most economical would depend on circumstances.

"With regard to the series arrangement I have already expressed my views at some length. I will not again enter into a discussion of the mechanical details the difficulty of running, changing and repairing a multiplicity of high-tension circuits, of the dangers to life and property, the practical demands of insulation, the liability of leakage, the unsatisfactory charac- 12635
ter of any measuring arrangement, and the complex character of electro-motive force regulators, and for securing continuity of circuit. But I wish to dwell for a moment on the mistaken idea that, leaving out the many disadvantages which must be inherent to any series system, there will be a great gain in economy.

"It has been admitted that the very high tensions which would obtain when lamps were arranged in series, if each lamp were of considerable resistance, would be objectionable. It then becomes necessary to use lamps requiring a low 12636
potential at their terminals. We must not fall into the error of thinking that because a lamp of 100 ohms resistance, with a potential of 100 volts, and hence a current of one ampere, will give an illumination of, say, 15 candles, that the same effect would be produced by one ampere in a lamp of one ohm resistance, requiring one volt potential, for if it were so this latter lamp would be 100 times as economical as the former. We must remember that there is a perfect definite law governing the relation of potential,

12637 current and resistance, and the energy expended in a unit of time.

*   *   *   *   *   *

"It seems unnecessary to longer dwell on the series system and its disadvantages."

THE EDISON LAMP.

"The lamp, as great an achievement as it is, is but one integral part of a thoroughly worked out and practical system, and, I may add the only one
12638 which is in actual operation to-day. Mr. Edison early recognized the fact that the production of a lamp was not the only desideratum, but that the distribution of electricity for the purposes of light and power as well would require the careful elaboration of a system of supply and demand, that all parts of such a system must be mutually dependent, and that they must be designed with reference to each other. Hence he laid down certain principles of guidance, and has worked steadily with one end in
12639 view to bring out a thoroughly practical, efficient, reliable and economical system. That he has done this, there is to me, after months of careful study, no doubt, and I cannot refrain from adding my testimony to the success of his labors.

"There was shown at the Crystal Palace a thoroughly good piece of engineering for the distribution of about 1,100 lights, standard and half standard, the equivalent of 800 to 850 A lamps. They were distributed over a wide extent and at a considerable distance from the
12640 dynamos. There were several distinct circuits, but all derived the current from one pair of mains and one set of dynamos."

*   *   *   *   *   *

"Not only was it a most successful piece of lighting, but a thorough piece of electrical engineering, and many of the essential features of the Edison system were in operation."

Mr. Sprague then considers with some detail the central station system of distribution devised by Mr. Edison, states that the theory advanced by certain electricians that his system of conductors

would act like a Leyden jar, or a condenser, is 12641
destitute of common sense, and entirely opposed to the clearest laws of electricity. He further says:

"The proper laying out of such a district is a matter of most careful engineering, involving the cost of land, property, labor, coal and copper; capital invested and interest required; depreciation of plant and life of lamps; in short, how much coal can be wasted and how much return is to be sought for. But it is perfectly practicable, and already is being accom- 12642
plished in New York. Since becoming thoroughly acquainted with this system I have had no doubt of its ultimate success, which recent developments show to be established. In the matter of making the transmission of light and power a practical success, in bringing it home to everyday domestic economy, Mr. Edison, without doubt, has done more than all others, and while his system is by no means yet perfect, it is unquestionably far ahead of the work of any one else."

12643

It is evident from these quotations from eminent electrical authorities that the problem which I have stated in my answer to Q. 7 was regarded, prior to the year 1880, as extremely difficult, if not impossible, of solution, and that while various means were suggested by one or another, some other electricians pointed out the insuperable objections to each method proposed, and it was not until the system of Mr. Edison came to be understood, after the year 1880, that electricians realized that the 12644
problem had been solved.

Objected to on the further ground that the quotations made by the witness, and alleged extracts from newspapers and reporters' interviews, are utterly incompetent, secondary, hearsay, irrelevant and immaterial, and that they are, upon the face of them, only extracts from the various publications referred to, and that the same cannot be understood properly without the full context of the

12645 various articles, and notice is given that a motion will be made to strike out this answer.

Adjourned until 12 o'clock to-morrow, December 10, 1890.

12646 NEW YORK, December 10, 1890,
12 o'clock.

Met pursuant to adjournment.
Present—Counsel as before.

CONTINUATION OF THE DIRECT EXAMINATION OF THE WITNESS, PROF. CHARLES F. CHANDLER:

9 Q. How long had incandescent lamps been known which were capable of use?

12647 Objected to as not matter in rebuttal.

A. Since 1845, when Starr invented his incandescent lamp; later, in 1873, Konn invented an incandescent lamp, and about 1878 Sawyer and Man, Edison and Maxim invented incandescent lamps. The Werdermann lamp, which is often called an incandescent lamp, was invented in 1878. There were many other incandescent lamps, as, for instance, the Woodward lamp, patented 1876. All of these lamps were capable of use, provided a proper
12648 system of distribution for the electric current were devised.

10 Q. Had the incandescent lamp of Mr. Edison been patented or described in any patents or applications of his prior to the application for the patent in suit; if so, in what one or what ones?

A. On November 4, 1879, Mr. Edison applied for a patent for an electric lamp, and the patent was granted on January 27, 1880, No. 223,898, about eight months before the application was filed for

the patent in suit. Mr. Edison says in his specifi- 12649
cation of this patent:

"The object of this invention is to produce electric lamps giving light by incandescence, which lamps shall have high resistance, so as to allow of the practical subdivision of the electric light.

"The invention consists in a light-giving body of carbon wire or sheets coiled or arranged in such a manner as to offer great resistance to the passage of the electric current, and
at the same time present but a slight surface 12650
from which radiation can take place.

* * * * * *

"Heretofore light by incandescence has been obtained from rods of carbon of from one to four ohms resistance, placed in close vessels, in which the atmospheric air has been replaced by gases that do not combine chemically with the carbon. The vessel holding the burner has been composed of glass cemented to a metallic base. The connection between the leading wires and carbon has been obtained by
clamping the carbon to the metal. The 12651
leading wires have always been large, so that their resistance shall be many times less than the burner; and, in general, the attempts of previous persons have been to reduce the resistance of the carbon rod. The disadvantages of following this practice are that a lamp having but one to four ohms resistance cannot be worked in greater numbers in multiple arc without the employment of main conductors of enormous dimensions; that, owing to the low resistance of the lamp, the leading
wires must be of large dimensions and good 12652
conductors, and the glass globe cannot be kept tight at the place where the wires pass in and are cemented, hence the carbon is consumed, because there must be almost a perfect vacuum to render the carbon stable, especially when such carbon is small in mass and high in electrical resistance.

"The use of a gas in the receiver at the atmospheric pressure, although not attacking the carbon, serves to destroy it in time by air washing, or the attrition produced by the rapid passage of the air over the slightly coherent, highly

12653 heated surface of the carbon. I have reversed this practice. I have discovered that even a cotton thread properly carbonized and placed in a sealed glass bulb exhausted to one-millionth of an atmosphere offers from 100 to 500 ohms resistance to the passage of the current, and that it is absolutely stable at very high temperatures.

* * * * * *

"By using the carbon wire of such high resistance I am enabled to use fine platinum wires
12654 for the leading wires, as they will have a small resistance compared to the burner, and hence will not heat and crack the sealed vacuum bulb.

* * * *

"I have carbonized and used cotton and linen thread, wood splints, paper coiled in various ways, also lampblack, plumbago, and carbon in various forms.

12655 I claim as my invention:

1. An electric lamp for giving light by incandescence, consisting of a filament of carbon of high resistance, made as described, and secured to metalic wires, as set forth.

2. The combination of carbon filaments with a receiver made entirely of glass, and conductors passing through the glass, and from which receiver the air is exhausted, for the purposes set forth."

12656 On February 5th, 1880, or six months before the application for the patent in suit, Mr. Edison filed an application for a patent for a method of manufacturing electric lamps, which was granted on July 20, 1880, and was numbered 230,255. Mr. Edison states in his specification:

"My electric lamp consists, essentially (as shown in prior applications of mine for patents), of an incandescing conductor of high resistance, hermetically sealed in a glass vacuum chamber.

"Great difficulty has always been experienced is so sealing a glass vacuum globe or 12657
chamber that complete union of the parts was had and danger of opening or separation avoided, in order that a stable vacuum might be maintained when the parts forming the seals were in vacuo when the sealing was done. In fact, the maintenance of a stable vacuum has been pronounced impossible by many scientists.

"The object of my invention is to furnish a method of manufacturing electric lamps so 12658
that a stable vacuum may be maintained therein."

This patent describes a method for successfully manufacturing a lamp embodying the elements described as characteristic of the electric lamp of patent 223,898, dated January 27, 1880. It gives the necessary directions to enable the glass-blower to prepare the proper bulb with the necessary tubes at each end, also to prepare the support
for the carbon filament and hermetically seal the 16259
platinum leading wires into the glass support. It then shows how the glass support of the filament is to be hermetically sealed into the base of the glass bulb. It then shows how the bulb is to be attached by the leading tube at the top to the air pump by which the vacuum is produced. And finally shows how, when the vacuum has been secured, this leading tube is to be melted off and the lamp completed.
The whole being illustrated by the drawings of 16260
the patent. The claims are:

"1. The method of forming electric lamps, substantially as set forth, consisting in separately forming the enclosing globe and the supporting bulb for the incandescent conductor attaching the wires and incandescent conductor thereto, and then hermetically uniting the parts prior to the formation of the vacuum, substantially as herein described.

"2. The method of hermetically sealing a

12661 vacuum chamber, substantially as described, which consists in first sealing in vacuo and then sealing in air, substantially as described.

These two patents describe substantially the Edison lamp now in use, and the method employed in manufacturing it.

11 Q. Did the invention of this lamp described in your last answer solve the difficulties in the way of distribution of electricity over large areas, or did it
12662 in any respect increase those difficulties; and if so, why?

A. The invention of this lamp did not solve the difficulties in the way of the distribution of electricity over large areas. On the contrary, it increased them, because this lamp is an extremely delicate device for producing light by the action of electricity. It is a lamp of high resistance, requiring for its safe and efficient use a current of uniform pressure, and this uniformity of pressure must be
12663 maintained over large areas at all times, whether few or many of the lamps are in use. There is no regulating device connected with the lamp, and, consequently, it is not in the power of the consumer to regulate the lamp so as to adapt it to varying conditions of electrical pressure in the distribution. All that the consumer can do is to turn it on or to turn it off. It is so delicate a device that the slightest increase of electrical pressure over that which it is designed to sustain results in rapid de-
12664 terioration and early destruction of the lamp. On the other hand, a very trifling decrease in the electrical pressure results in so seriously diminishing the illuminating power of the lamp as to materially interfere with its usefulness. In fact, to operate the best constructed lamps of the character described in these patents, it is necessary that the extreme variations in the distribution of the electrical current should not exceed a very small percentage, say five per cent. or even two per cent. No such system of distribution was known, as far as I am aware, at

the times when the applications for these two lamp 12665
patents were filed or when they were granted.

12 Q. Had the general characteristics of the systems of electrical lighting, to which the invention of the patent in suit was applicable been referred to any prior application for patents by said Edison? If so, please refer to and quote from any such prior applications now available to you?

A. The general characteristics of the system of electric lighting to which the invention of the patent in suit was applicable had been clearly set forth 12666
in prior application for patents filed by Mr. Edison. On February 5, 1880, Mr. Edison applied for a patent for a system of electrical distribution, six months before the application for the patent in suit. This patent was not granted until August 30, 1887. It is numbered 369,280.

"The object of this invention is to arrange a system for the generation, supply and consumption, for either light or power or both, of elec- 12667
tricity, that all the operations connected therewith requiring special care, attention or knowledge of the art shall be performed for many consumers at central stations, leaving the consumers only the work of turning off or on the supply, as may be desired; in other words, to so contrive means and methods that electricity may be supplied for consumption in a manner analogous to the systems for the supply of gas and water, without requiring any greater care or technical knowledge on the part of the consumer than does the use of gas or water, 12668
in order that economy, reliability and safety may be ensured.

"In carrying the invention into effect a city, town, village or locality may form one district, or, if the extent of territory makes it desirable, may be divided into several districts. In each district I provide a central station, at which are grouped a suitable prime motor or several motors, dependent upon the amount to be supplied, generators or means for converting the prime motive force into electricity, and means for determining and reg-

12669 ulating the amount of electricity generated and supplied, in order that a constant pressure of electricity (so to speak) may be kept up.

* * * * * *

"At the central station all the supply generating coils or batteries thereof are connected to conductors on the multiple arc system, and from these conductors at the station main conductors (which for convenience may be called simply the 'mains') connected thereto, also on the multiple arc system, lead in any and
12670 all desired directions for conveying the energy to points where work, either by translation into light or motive power, is to be done. All of such conductors from the generators at the station to the lamps are made in pairs; one for the outgoing current and the other for the returning current of electricity, the currents throughout the system being complete or round metallic circuits, the conductors of which are well insulated from each other and from the earth. The use of the earth for one-half of the circuit
12671 would largely increase the difficulties arising from the grounding of the conductors or the crossing of the conductors among themselves, or with the conductors or other circuits to such an extent that a system so constructed would be impracticable."

* * * * * *

"To avoid any appreciable variations and ensure uniformity, it is essential that any lessening of pressure be immediately indicated, in order that just sufficient pressure be gen-
12672 erated and sent out to keep up an equal flow through the circuit of each translating device—that is, that the pressure be kept up uniform, whether more or less translating devices be in circuit. This is attained by providing at the central station means for constantly indicating the pressure, and for regulating the production, if appreciable variation be indicated. At each central station test lights are arranged, so that an approximate visual test of the effect of pressure upon the circuit of any translating devices in use may be shown. From what has been said, it is evident that more or less translating devices are brought into circuit, the

total resistance of the circuit, or all the circuits 12673
thereof, to the flow of all the current generated varies. To indicate this, electro-dynamometers, galvanomters or electrometers are placed across the main conductor at the central station, or by return wire at any point in the circuit, with a zero mark placed to correspond with the deflection consequent upon the maintenance of the proper amount of pressure."

* * * * * *

"As ordinarily proposed, each electric light requires its own regulator, which usually is either
thermostatic or magnetic, breaking the circuit or 12674
bringing in resistance; in any case making a cumbrous lamp, requiring delicate management and constant attention. By regulating at the central station entirely, I am enabled to use a small separate lamp, which may be used with the exercise of no more than ordinary care or attention."

There are eight claims to this patent, each claim including more or less of the different elements em-
bodied in the system. Claim 8 seems to be the most 12675
comprehensive, and I therefore quote it:

"8. In a system for the generation and distribution of electricity for light or power through cities or towns, or districts thereof, a central station whereat are combined a number of generators of electricity connected in multiple arc, and consisting each of an armature revolving in a magnetic field, an indicator of electric pressure and a regulator of the current generated, conductors forming complete
or round metallic circuits leading from such 12676
station to distribute the current throughout the system, translating devices connected in multiple arc with such conductors, and meters in the houses for measuring the current supplied to such translating devices, substantially as set forth."

On August 6th, 1880, three days before the date of the filing of the application for the patent in suit, Mr. Edison filed an application for a patent for an electric lamp, in which he describes the system in

12677 connection with which he intends to make use of the said lamp. This patent was granted March 22, 1881, and is numbered 239,150. Mr. Edison says in his specification of this patent:

"In a system of electric lighting such as proposed by me, in which separate electric lamps devoid of regulating devices are used at the place of consumption, the entire regulation for all the lamps being performed at the central station, as with water or gas supply, 12678 it is essential that a constant electromotive force or pressure be maintained; and as in such a system the lamps are arranged upon the multiple arc or derived circuit system, it is essential that there should be a certain standard resistance in each derived circuit. This has been attained by placing one lamp of such standard resistance in each derived circuit.

"It is desirable that all lamps used should be of equal lighting value, each giving a certain standard amount of light. This has been attained by giving each a certain definite or standard 12679 amount of radiating surface. Ordinarily this radiating surface has been that which, with the standard pressure or electro-motive force and the standard resistance, should give a light equal to sixteen candles."

CLAIMS.

"1. The combination with one derived circuit of a multiple arc system of two or more lamps each of a fractional resistance and radiating surface of the resistance and radiating sur- 12680 face of the standard lamp of the system, the fraction being the number used, substantially as set forth.

"2. The combination with one socket or holder and a derived circuit of one circuit controller and of two or more lamps, each of a fractional resistance and radiating surface of a standard lamp, substantially as set forth."

Adjourned until to-morrow, December 11, 1890, at 12 o'clock.

NEW YORK, December 11, 1890, 12 o'clock. 12681

Met pursuant to adjournment.

Present—Counsel as before.

CONTINUATION OF THE DIRECT EXAMINATION OF THE WITNESS, PROF. CHARLES F. CHANDLER:

13 Q. What are the elements which you under- 12682 stand to constitute the combinations recited in the first three claims of the patent in suit?

A. Each claim involves four elements:

FIRST. Incandescent lamps grouped in large numbers into one system and arranged in multiple arc in an all-round metallic circuit, and uncontrolled from the central station as to the number in use by the consumer.

SECOND. A central station for supplying and 12683 regulating the current.

THIRD. A set of conductors with which no translating devices of any kind are connected, and whose function is to carry the current, and to meet the difficulty involved in carrying it to a distance without exceeding practical limits in the size, weight and cost of metal. This involves the localization or concentration in the feeders of all drop in tension beyond a negligible amount (and such an excess of 12684 drop must exist somewhere in a system involving large numbers of lamps, large areas and reasonable economy in conductors).

FOURTH. A consumption or service circuit which is so proportioned or limited in reference to the number and location of the lamp connected with it that there is no essential drop in tension between the lamps nearest to the source of electricity and those most remote from it.

12685 The first claim is as follows:

> "1. A consumption circuit in the main conductors of which the drop in tension is not sufficient to vary practically the candle-power of the lamp connected therewith, in combination with feeding conductors connecting the consumption circuit with the source of electrical energy, and having no translating devices connected therewith, the drop in tension upon such feeding conductors not affecting the relative
> 12686 candle-power of the lamps of the consumption circuit, substantially as set forth."

This first claim shows no fixed relation between the loss of pressure on the feeder and the loss on the mains. It implies that the loss on the feeder and mains together would be sufficient if lamps were placed on the feeders as well as on the mains to affect the relative candle-power of the lamps. It is also evident from this claim that the
12687 feeding conductor must have such length as to involve a substantial drop in tension.

The second claim shows a fixed relation between the drop on the feeding conductor and the drop on the consumption circuit. It says:

> "The loss upon such feeding conductors being greater than upon the main conductors of the consumption circuit."

The third claim is limited to the case in which
12688 the feeding circuit is connected with the consumption circuit at its geographical center. The object of this arrangement is to secure still further economy in copper. These three claims are limited to the use in connection with this system of distribution of incandescent lamps, no other translating devices being included. I am aware that the preamble of the specification contains some general words which might include other translating devices; no others are, however, specifically referred to in the specification, while the first three claims

specially call for lamps as distinguished from other 12689
translating devices as essential elements of the claims. The other three claims, that is, the fourth, fifth and sixth, might possibly be satisfied by using other translating devices.

14 Q. What are the advantages derived from the invention of the patent in suit as recited in the first three claims?

A. This system was the first system invented which made domestic electric lighting possible, be- 12690
cause, first, it produced means by which electricity could be practically distributed; that is, by which it could be divided over a considerable area, without incurring prohibitory expense for conductors; second, it for the first time permitted the use by consumers on large systems of simple, unregulated lamps, by providing an organization of circuits on which by central station regulation a constant potential or pressure, notwithstanding variable load (that is, more or less 12691
lamps in use at one time), could be maintained at each and all of the lamps without endangering either their life or their usefulness.

15 Q. Assuming that other translating devices were or had been used in connection with such an arrangement of conductors as is described and claimed in the first three claims of the patent in suit, would it, in your opinion, involve invention to discover the applicability of the circuits in ques- 12692
tion for use in connection with incandescent electric lamps and for the purpose of maintaining equality of pressure at a number of such lamps scattered over a large area, and, in fact, to so use such lamps in such combination as distinguished from the use of such circuits in connection with other forms of translating devices?

A. Even though it should be found that other translating devices had been used in connection with such an arrangement of conductors as is de-

12693 scribed and claimed in the first three claims of the
patent in suit, it would, in my opinion, involve in-
vention to discover the applicability of the circuits
in question for use in connection with incandescent
lamps and for the purpose of maintaining equality
of pressure at a number of such lamps scattered
over a large area. My reason for this opinion is
because the incandescent lamps were such a differ-
ent and delicate translating device that it would
require experiment and invention to adapt such a
12694 circuit as is described in the first three claims of
the patent to such a delicate device. As I have
already stated in my answer to Q. 11, the invention
of the Edison incandescent lamps increased the
difficulties of providing the proper electricity, or
proper current of electricity, for their use. These
lamps are of high resistance and they require for
their safe and efficient use a current of uniform
pressure, which uniformity of pressure must
be maintained over large areas at all times,
12695 whether few or many of the lamps are in use.
There is no regulating device connected with
the incandescent lamp, and consequently it is not
in the power of the consumer to regulate the lamp
so as to adapt it to varying conditions of elec-
trical pressure in the distribution, as can be done
with gas and water. All that the consumer can do
to the incandescent lamp is to turn it on or turn it
off. With gas and water there is always an ad-
justable stop-cock at each opening or translating
12696 device, by which the current of gas or water can be
regulated at will. The special delicacy of the in-
candescent lamp is shown by the effect of the slight-
est variation of the electrical pressure from what it
is designed to sustain. If the pressure is slightly
increased, the filament of the lamp is rapidly disin-
tegrated, which results in the early destruction of
the lamp. On the other hand, if the pressure of
the electrical current is slightly diminished, the in-

candescence of the filament falls and the lamp 12697
ceases to give the required amount of light.

* * * * * *

17. Q. Was there anything in the knowledge of working of small plants, involving the use of only a small number of lights and short distances to be traversed, on which drop in tension was unimportant to teach either the necessity or utility of the invention in question?

A. There was not. In such plants as are men-
tioned in the question, the difficulties to overcome 12698
which is the object of the invention described and
claimed in the patent in suit, would not be en-
countered. With limited numbers of lamps dis-
tributed over small areas, there would be no diffi-
culty in providing conductors within reasonable
limits of expense, which would supply the current
to all the lamps near and remote, without involving
such a drop in potential as would interfere either
with the durability or the usefulness of the lamp.
Consequently, in establishing such plants, no 12699
knowledge or experience would be gained with re-
gard to the necessity of providing distribution for
large numbers of lamps distributed over large
areas. Experiment and invention would be neces-
sary to meet the requirements of this latter case.

* * * * * *

34 Q. I call your attention to the statement on
page 435 of defendants' record, by Mr. Pope, that
he had made some experiments with the Roberts
and Havell electro-plating plant by means of two 12700
Edison incandescent lamps constructed to burn at a
potential of three volts.

Please state whether you know what such Edison lamps are, and whether any test made with such lamps would be of any importance?

A. I am familiar with Edison lamps of the kind used by Mr. Pope in his experiment, and in my opinion experiments made with such lamps are of no practical value, and the tests made with them would be of no practical importance. These lamps are not

12701 intended and are not used for artificial illumination
in the ordinary sense of the term. They are special
lamps constructed either to be used as toys for
Christmas trees or ladies' hair, or for lighting the
interior of the mouth or the stomach. They are
little things from a quarter to a third of an inch in
diameter. They have an illuminating power of
one-half of one candle. The carbon filament con-
tained in them is about one-eighth of an inch long,
and I never have seen one of them used as an
12702 ordinary source of light for illuminating purposes
—that is, as a substitute for a gas burner or a kero-
sene lamp.

* * * * * *

CROSS-EXAMINATION BY MR. CURTIS:

38 x-Q. And, as you understand it, the term
"sub-division of the electric light," as commonly
understood and used prior to 1880, was used to
12703 designate a system of distribution such as you refer
to in your answer to 7 Q.?

A. The term "sub-division of the electric light"
was used to express the idea of a number of small
electric lights of moderate illuminating power in
place of one or any small number of electric lights
of great illuminating power. I do not think that
prior to 1880 many, if any, of the writers realized
all that was necessary in order to accomplish this
result. That is, they did not realize all the condi-
12704 tions which have since been found necessary which
obtain in modern incandescent lighting practice,
and which I have endeavored to enumerate in my
answer to 7 Q. In fact, I think most of these writ-
ers thought it impossible to solve the problem. I
think, therefore, that the term "subdivision of the
electric light," as commonly understood and used
prior to 1880, was used to designate a system of dis-
tribution such as I refer to in my answer to ques-
tion 7; but that the writers did not realize all that
was required to make such a system successful.

39 x-Q. But, as I understand you, the problem 12705
of "subdividing the electric light," as understood
prior to 1880, was a problem of distribution of the
current, so as to produce the general result to which
you refer in your answer to question 7. Is that
your understanding of the sense in which the term
was understood and employed prior to 1880?

A. That is only a portion of the sense in which
the term was used. It was used in a larger sense.
It not only included the proper distribution of the
current, but it included, in addition to this, select- 12706
ing the proper kind of current and the proper de-
vices for converting electrical energy into the de-
sired kind of light, and doing this in a manner suf-
ficiently economical to make it commercially prac-
ticable. And also accomplishing this over compar-
atively large areas.

40 x-Q. At the conclusion of your answer to
question 8, you say that it is evident from the
quotations you have made in the preced- 12707
ing part of your answer, that the problem
which you stated in your answer to question 7
was regarded prior to the year 1880 as extremely
difficult, if not impossible of solution, and it was
not until the system of Mr. Edison came to be un-
derstood, after the year 1880, that electricians real-
ized that the problem had been solved. Do you re-
fer here to the problem commonly referred to prior
to 1880 as the subdivision of the electric light?

A. I do; using the expression "subdivision of 12708
the electric light" in the broad sense which I have
indicated in my last answer.

41 x-Q. What system do you refer to here as the
"system of Mr. Edison?"

A. I refer to the comprehensive system of incan-
descent lighting for domestic purposes embodying
the conditions enumerated in my answer to said
question, of which the invention described and
claimed in the first three claims in the patent in

12709 suit is an essential part, and as far as the system is limited to distribution it is this particular feature to which I refer.

42 x-Q. Do you mean to be understood by the last part of your answer to Q. 8 that, as you understand it, Mr. Edison solved the problem which, as you had stated, was regarded prior to the year 1880 extremely difficult if not impossible of solution?

12710 A. I do.

43 x-Q. Do you hold the opinion that the invention described and claimed in the patent in suit, No. 264,642, is what constituted the practical solution of the problem of the subdivision of the electric light, which was regarded prior to 1880 as extremely difficult, if not impossible of solution?

A. I do regard this as the most essential feature of the problem. There were other minor features
12711 which were also important to make this kind of electric lighting commercially successful, but the distribution was the main feature of the problem, and that was solved by the invention described in the patent in suit.

44 x-Q. But you do not regard the invention described in the patent in suit, as taken by itself and with what was known in the art, without other invention, as constituting a practical solution of the
12712 problem of subdivision—do you?

A. The invention in the patent in suit solved the problem of distribution and made it possible with lamps that had already been invented, dynamos already in use or invented, to put this kind of subdivision of electric lighting in practice, though it is undoubtedly true that other inventions made in the years immediately preceding and succeeding 1880, by Edison and others, have largely contributed to the general success of this method of electrical illumination.

45 x-Q. Assuming the state of the art existing in 12713
1879 at the time when the various witnesses whose testimony you have quoted were examined before the Parlimentary Committee, would the invention described and claimed in the patent in suit, without any further invention by Mr. Edison or any one else, have constituted, in your opinion, a practical solution of the problem of the subdivision of the electric light, which you have said was regarded as very difficult, if not impossible of solution, by those witnesses? 12714

A. It would, for the reason that the three elements necessary would have been available: incandescent lamps, the source of electricity, that is, dynamos, and the Edison system of distribution by which the current could be supplied to the lamp under suitable conditions.

46 x-Q. What incandescent lamps were available at that time which, in your opinion, would have been suitable for the purpose and capable of commercial use? 12715

A. There was the platinum lamp, of which several forms have been invented, for instance, by Moleyns in 1841, De Changy in 1858; also by Mr. Edison and Lane-Fox; then there were several carbon lamps, as for instance, the lamp of Starr and King, of 1845; of Greener and Staite, of 1846; of Lodyguine and of Kosloff, 1873; of Konn, 1875: Woodward, 1876; of Sawyer-Man, 1878, and about the date of this report, though the patents were is- 12716
sued perhaps a little later, the Edison lamps, the Swan lamps, the Lane-Fox lamps.

47 x-Q. Which of these lamps, if any of them, were practically useful lamps, in your opinion, for purposes of commercial illumination?

A. That is a very difficult question to answer. Incandescent lamps have been so much improved since that date that all of the lamps that were known prior to the middle of the year 1879, at least generally known, are so inferior to the incandescent

12717 lamps of Edison, Sawyer-Man, and, in fact, most of the other makers of lamps at the present time, that they would not be commercial to-day, and yet I think most of them could have been used commercially if a proper system of distribution had been known. Nevertheless, it should not be forgotten that the improvements which have been made in incandescent lamps since 1879 have made the problem of distribution much more difficult than it was before, because the lamp of to-day is a far more deli-
12718 cately organized structure than were the lamps that were known prior to the middle of 1879.

48 x-Q. Are you prepared to say that there was any incandescent lamp known at the date of the report of the English Parlimentary Committee, June 13th, 1879, which was a practically useful lamp for commercial illumination, and suitable for use with such a system of distribution as is described in the patent in suit?

12719 A. I think there were several; I think the Konn, the Woodward and the Sawyer & Man, and possibly two or three others that I mentioned could have been practically used. They would, of course, be very poor affairs compared with the lamps of to-day, and with their use electric lighting would not have been as economical as it is now. Perhaps fewer customers would have introduced the light had it been offered; but, without considering the commercial question, which depends upon a great
12720 many conditions, I think some at least, if not all of these lamps, could have been practically used. They were not used practically for the reason that with the successful invention of the distribution system came a number of new lamps which were so much better than the old ones that when practical electric lighting was adopted, the improved lamps were employed.

It is impossible to say at this time to what degree practical electric lighting would have become successful, after the invention of the patent in suit, had

no improvement been made in incandescent lamps. 12721

49 x-Q. It is, then, your opinion that the invention described and claimed in the patent in suit constituted in itself a practical solution of the problem of the subdivision of the electric light, without taking into account any other invention or improvements made in incandescent lamps, dynamo machines or other apparatus after the time when the witnesses referred to gave their testimony before the parliamentary committee? 12722

A. In one sense it is my opinion that the invention of the patent in suit constituted a practical solution of the problem of the subdivision of the electric light. There were dynamos and there were lamps that could be used with the proper system of distribution. Whether they would have been used had the development of electric lighting gone no further than the patent in suit, it is impossible for anyone to say. For, at or about the time this patent was taken out, so many other inventions and im-
provements were made, all of which contributed 12723
more or less to the practical solution of the problem, that when the first practical attempt to provide electric lighting by means of a large number of lamps distributed over a considerable area was made, neither the old lamps nor the old dynamos were employed. I do not mean to say that the invention of the patent in suit was all that was desirable or necessary in order to solve the problem of what was called, in 1879, subdividing the electric light. A
great many things were necessary, and a great many 12724
inventions contributed to the successful solution of the problem. The distribution was an essential feature, an essential element, but improved lamps, improved dynamos, meters, junction boxes, safety plugs, pressure wires, regulating devices and many other things contributed to the practical solution. Mr. Edison invented the system of distribution; he also invented all the other items that I have enumerated, and the Edison system in its broadest sense includes them all. I do not think,

12725 on the whole, that it can be said that the invention described and claimed in the patent in suit constituted by itself, without taking into consideration the other inventions that I have enumerated, a practical solution of the problem of the subdivision of the electric light.

50 x-Q. You are quite sure, however, that Mr. Edison invented everything else which was necessary for the practical solution of the problem?

12726 A. I think he did. I do not mean that he is the only person who invented improved lamps or improved dynamos or safety devices, etc., but I think he invented a complete system of incandescent electric lighting, including all the essential elements necessary for practical commercial success.

51 x-Q. It is a fact, is it not, that Mr. Edison or his company has several hundred patents on other parts of the system such as improved lamps, improved dynamos, meters, junction boxes, safety

12727 plug, pressure wires, regulating devices and many other things which have contributed to the practical solution of the problem?

A. It is.

52 x-Q. It is a fact also, is it not, that Mr. Edison or his company has a large number of patents besides the one in suit, upon the system of distribution used in the Edison system?

A. It is.

12728 * * * * * *

NEW YORK, January 12th, 1891, 2 P. M. 12729

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF THE WITNESS PROF. CHARLES F. CHANDLER CONTINUED:

55 x-Q. In the last part of your answer to Q 8 you apparently refer to a part of the publications from which you quote extracts, as showing that up to a certain time the problem stated in your answer 12730 to Q. 7 was regarded as extremely difficult if not impossible of solution, and to a part of such publications as showing that electricians realized that the problem had been solved after that time. Please state which of the said publications you intended to include in the first class, and which in the second?

A. The following authorities from whom I have quoted regard the problem as difficult or impossible of solution: Siemens, Cooke, Preece, Deacon, 12731 Woodall, Thomson, Michael, Trant, Morton, Shoolbred and Briggs, although Thomson, Michael and Briggs express a belief that the problem will be solved.

The following authorities from whom I have quoted regard the problem as having been solved subsequently to the year 1880: Swan, Lungren, Sprague and the editor of the "Scientific American."

* * * * * * 12732

62 x-Q. Referring now to the testimony of Mr. Cooke, from which you quote in your answer to cross-question 57, do you understand that the loss from subdivision referred to by this witness was due in any way, as he understood it, to the resistance of the conductors?

A. I think Mr. Cooke realized the existence of a loss due to the resistance of the conductor, though it is true that he had in his mind, while undergoing

12733 his examination before a Parliamentary Committee, another loss, which he attributes to the substitution of several small arc lights for one large arc light. This he refers to in his answers to questions 357 and 358. In his answer to question 388, where the question refers to a closed circuit and incandescent lamps, he certainly cannot refer to the kinds of loss which he refers to in 357 and 358, for arc lights are not under discussion; and yet he says, in his answer to 388, that in the case of incandescent lamps and
12734 closed circuit there will be a far greater loss. It might be claimed, however, that in his answer to 388 he is comparing incandescent lamps on a closed circuit to one single arc light produced by the same amount of energy. In his answer to question 421, as well as in his answer to question 419, he speaks of divided currents, and a loss resulting from such division, as expensive and uneconomical as compared to the system in which one machine is used for each light. This, I think, refers to his idea of the loss
12735 due to using several arc lights instead of one.

There is nothing in these answers to indicate that he referred to loss in the conductors. In his answer to question 425, referring to Mr. Edison's alleged invention, he expressed incredulity at the statement that Edison has succeeded in running two hundred lights on one circuit, but he doesn't refer to any particular reason for his incredulity.

I must say, after carefully looking through Mr. Cooke's testimony again, that I do not find any
12736 distinct reference to a loss from subdivision due to the resistance of the conductor.

63 x-Q. Mr. Preece testified before the same Parliamentary Committee as follows:

> "510. I think you have both considered and made experiments upon the subdivision of the electric current for the production of various lights?
>
> A. I have; I have examined the questions theoretically from a mathematical point of

> view, and I have also examined it experimentally. 12737
>
> 511. Did you not publish a paper upon the subject in the January number of the "Philosophical Magazine?"
>
> A. I did.
>
> 512. What was the result that you came to?
>
> A. In that paper I showed first of all that there are two ways of subdividing the light. Supposing that this piece of string which I hold in my hand were a wire, conveying a current, we might insert in that one string several lamps, or we might take these several lamps 12738 and join them in what is called a parallel arc. You may have your wires arranged parallel with each other, with one lamp in each. The result of my inquiry was to show that when lamps are joined up in the series the intensity of light in each lamp diminishes with the square of the number inserted; and when they are joined up in this parallel arc the intensity of the light diminishes as the cube of the number, showing that when you attempt to subdivide the light between two or three, the intensity of the light diminishes in a marvellous 12739 ratio."

Do you understand that Mr. Preece here refers to the same causes of loss from subdivision which Mr. Cooke had in mind in giving the testimony to which you have referred?

Adjourned to Wednesday, January 21st, at 11 o'clock A. M.

12740

12741 NEW YORK, Wednesday, January 21, 1890,
11 A. M.

Met pursuant to adjournment.
Present—Counsel as before.

CROSS-EXAMINATION OF PROFESSOR CHARLES F. CHANDLER BY MR. CURTIS:

A. I do.

12742 64 x-Q. Mr. Preece's paper in the "Philosophical Magazine," here referred to by him, purports to be a mathematical demonstration, does it not, of the conclusions, stated in his answer to question 512, that when lamps are joined up in series the intensity of light in each lamp diminishes as the square of the number, and when joined in multiple are as the cube of the number, and this without taking into account the distance of the lamps or any of them from the battery or dynamo?
12743 A. That is so.

65 x-Q. I notice in this article in the "Philosophical Magazine" Mr. Preece refers to chapter 11 of Fontaine's Electric Lighting as authority for the statement he makes that experiment has proved the ultimate possibility of extensive subdivision to be fallacious. Please examine chapter 11 of the work referred to, which I now hand you, and particularly pages 218 to 223, and state whether or not
12744 the experiments of Fontaine there described do not apparently substantiate the statements made by Mr. Preece under the conditions adopted by Mr. Fontaine in making the experiments?
A. They do.

66 x-Q. Is there not this fallacy underlying both of Fontaine's experiments and Preece's mathematical computations that they both assumed that the smaller lights were to be obtained without change in the construction of existing lamps by delivering a smaller current to each lamp, thus re-

ducing the temperature of the burner at 12745
each lamp, and the amount of light emitted by it. And was not the enormous loss of energy by such subdivision as they assumed due to the fact that the heat developed in the burner decreases in a much greater ratio than the decrease in the current, and the light produced in turn decreases much more rapidly than the heat.
A. This is true.

67 x-Q. Is it not a fact that this same fallacy was 12746
very commonly adopted by electricians and scientific men prior to 1880, and that the opinions expressed by them in regard to the difficuly or impossibility of subdividing the electric light were based for the most part upon this fallacy?

A. It is quite true that this fallacy was very prevalent among the electricians who discussed electric lighting prior to 1880, and quite a number of witnesses who testified before the Parliamentary
Committee seemed to be impressed with the idea 12747
that the light produced will diminish in the ratio of the square of the number of arc lights supplied by a given current, and as the cube of the number of lights in some cases. This is, however, only one of the fallacies prevalent at that time with regard to electric lighting, and it shows how little was known by the electricians at that time with regard to the conditions involved in the problem of successfully evolving electricity for illuminating purposes. It shows, too, how different the problem of 12748
electric lighting was from the problems involved in gas and water engineering, about both of which there was really as much known prior to 1880 as at the present day.

I do not find that Woodall, Thompson, Shoolbred, Briggs or Swan labored under this fallacy.

Thompson, in his answer to question 1780, makes the following statement:

"1780 Q. But there is nothing in the mathematical discussion of the question that should

12749 render that reduction necessary by the square or the cube?

> A. No; it is quite possible that a plan of using electric energy for light might be found and may yet be found, in which ten feebler lights will give a light equal to that obtainable by the same energy in one concentrated light."

Mr. Briggs, in the article to which I referred in my answer to question 8, which was originally published in "Engineering," October, 1878, and after-
12750 wards reprinted in the "Journal of the Franklin Institute," makes the following statement:

> "The problem of electric lighting to-day is the production of small enough quantity of light with equal economy to that attained for large illuminating effects, and of the distribution into small sources of light of the great light capacity now obtained at a single point of omission. To these ends the intelligence of all electricians is now directed, and the attainment of some measure of success can be confidently
12751 anticipated."

This same Mr. Briggs, in an article which was published in "London Engineering," October 11, 1879, and which was reprinted in the "American Gas Light Journal" for January 2, 1879, page 13, makes the following statement:

> "The electric light, wherever it is desirable to illuminate from one point, either at considerable distance or by great volume of light, therefore, is greatly more economical than gas light
12752 at the present time, with a promise of yet higher relative efficiency. And the adaptability of the electric system to smaller or even domestic uses would seem to be only a question of time for research and ingenuity to mature."

Professor Morton, in his lecture upon the electric light, before the American Gas Light Association, on page 4 of the "American Gas Light Journal" for January 2, 1879, appears to adopt this fallacy, and he gives there the figures of the experiments described in Fontaine's book, which go to show that

the loss of light, when the arc light is subdivided, 12753
is as the square of the number of lights; but he evidently knows that these experiments are misleading and that the conclusions are fallacious, for at the very end of his lecture, on page 77 of the "American Gas Light Journal" of February 17, 1879, he makes the following statement:

> "Heretofore the electric lights have only been practically developed in a concentrated form, and it certainly has not yet been shown that when divided there will be an enormous 12754
> loss of efficiency. Gas, on the contrary, has heretofore only been practically used in its divided form, and there can be no doubt that its efficiency is capable of much increase when it is burned in a concentrated manner.
>
> "It is here where the actual contest will come in, and the relative success of the two sources of light in each field will depend upon what it will accomplish in that field and not in some some other. In other words, we must compare the divided electric light (say Mr. Edison's when they become visible) with ordinary burners, 12755
> and the electric arc light with the lime light or some such concentrated form of gas burning."

That Professor Morton fully realized the difficulty of distribution as a distinct feature of the problem is shown by his remarks as reported by the reporter of the "New York Times," and published in the issue of December 28, 1879, which is printed in the defendant's record, on pages 382, 383, 384 and 385. He says: 12756

> "Next comes the difficulty of distributing on any large scale the immense electric currents which would be needed, and to provide for their equal action at different points, under varying conditions of the number of lights used."

Although Mr. Siemens is evidently committed to this fallacy, he was, nevertheless, in 1879, aware of what Mr. Edison claimed to have accomplished, as

12757 is shown by his answers to questions 259, 260 and 261, which I quote:

> "259 Q. Has your attention been called to some of the more recent experiments of Mr. Edison, and to the success which he is stated to have achieved in subdividing the light and making it applicable for rooms and dwellings, and so on, with great ease and cheapness?
>
> A. I have, and I think Mr. Edison can, no doubt, produce by his means a very steady and possibly an agreeable light.
>
> 12758 260 Q. And a cheap light he claims, I believe?
>
> A. Dynamically speaking, I think he has to prove his case, as yet. Our experience, as far as I can judge from my own, leads me to an opposite conclusion.
>
> 261 Q. That is, to a conclusion opposite to that which is said to have been the result of Mr. Edison's recent experiments?
>
> A. Yes, the dynamo machine which Mr. Edison proposes, I think, is not promising."

12759 Mr. Siemens' doubts here seem to refer to the means of producing the electric current, and not to the division of the lamp. Mr. Siemens returns to the subject in his answer to question 297, which is as follows:

> "297 Q. You would say that for such purposes as footlights and sidelights, which require constant modification of the light, at present at any rate, whatever your experience may lead you to in the future, the electric light
> 12760 is hardly a suitable light?
>
> A. Such a light, for instance, as Mr. Edison proposes now, I think, would be much more controllable in that respect than the electric arc. The electric arc cannot be varied in its intensity and brilliancy so readily as gas; but if the light is produced by igniting a piece of iridium or platinum wire, then it is easy enough to modify the current so as to give only a small amount of radiated light.

It is evident that Mr. Siemens was fully aware of the drop in tension which invariably occurs in a

conductor through which the current of electricity 12761
is sent to the lamps. This is clearly shown by his answers to questions 193, 194 and 276, which I quote:

> "193 Q. With regard to the question of having central stations of electrical energy, how would you think that this is likely to be brought into practice in the future?
>
> "A. I believe that if central dynamical stations were established in populous neighborhoods, the current could be divided within a circle of, say, two or three miles diameter, with- 12762
> out any serious loss of energy.
>
> "194 Q. Would you not require very large conductors?
>
> "A. You would require large conductors, but these large conductors would be capable of transmitting very large amounts of electrical energy. I may here mention, perhaps, that two years ago I suggested, as a mere thought, the possibility of carrying power from a large waterfall to a distance of some 20 or 30 miles for distribution, and I then came to the conclusion that it would probably require a conductor or copper 12763
> rod of three inches in diameter to convey the energy of 1,000 horses. But further consideration has led me to the conclusion that a much smaller conductor would be sufficient for that purpose. In fact, the only limit to the transmitting power of a long conductor is its liability to become heated, for in transmitting an electric current through a conductor a portion of the dynamical effect of the energy is lost and converted into heat, which heat accumulates in a conductor and has to be disposed 12764
> of by radiation or conduction. If the resistance of the conductor is made equal to that of the dynamo machine itself, it follows from Dr. Hopkins' recent experiments that the loss does not exceed the equivalent of ten per cent. of the power employed. One-tenth of the total power employed at the central station would therefore go to heat the conductor, and if the conductor is exposed to the cooling action of the atmosphere it will be capable of transmitting a vast amount of electrical energy before it will become heated to any consider-

12765 able extent; so that I now believe that a conductor of two inches would probably suffice to convey electric energy equal to 1,000 horse-power to a distance of 30 miles.

"276 Q. You have said that the electric light is cheaper the more it is concentrated: am I right in understanding that the loss of power depends upon the subdivision of the light rather than upon the distance which the current has to travel?

A. Both of those conditions have their effect. The distance to which a current has to travel
12766 would only increase the resistance, if the conductor was not increased; but if I had to increase my distance to, say, twice the distance originally existing between the source of power and the electric light, and I made a long conductor of twice the area, then the electrical resistance would be the same in both cases and the loss would be the same. Distance does not *a priori* imply loss of power; it implies weight of conductors; but subdivision of the electric light implies a loss which cannot be obviated.
12767 In dividing the focus of light into two foci, each of these two foci would not give half the amount of light produced by the original focus."

Mr. Thomson is evidently fully aware of the loss of energy and the consequent drop in tension which occurs when electricity is distributed. On page 194 of the Parliamentary Report, which I have already frequently quoted, he makes the following statement:

12768 "That is to say, a copper wire of half an inch diameter suffices to transmit 21,000 horse-power to a distance of 300 statute miles, with an expenditure of 26,250 horse-power at the sending end. The 20 per cent. loss being 51,250 horse-power is spent in generating heat all along the three miles of conductor, which is at the rate of 17.5 horse-power per mile, or one horse-power per 300 feet."

This Parliamentary Committee evidently realized that the division of the light itself was not the only problem that had to be solved in order to make

domestic lighting a success. On page IV. of the 12769
report, the committee says:

"So far as we have received evidence no system of central origin and distribution suitable to houses of moderate size has hitherto been established."

Mr. Swan, in his lecture before the Literary and Philosophical Society of Newcastle-on-Tyne, in 1880, printed in the "Scientific American Supplements,"
Nos. 264 and 265, already in evidence, in discussing 12770
Mr. Edison's plans as compared with his own, makes the following statement:

"The resistance offered by a filament of carbon in its best state for incandescent lamps, as thin as it is safe to use in a lamp, and of a length sufficient to give, say, a light equal to one burner, or ten standard candles (a unit of light, which I think we must not go beyond in planning an extensive system of town lighting) will not offer so high a resistance as that which
Mr. Edison has made the basis of his scheme of 12771
distribution.

With lamps of this resistance the results would be that, before many were bridged across from one main wire to another, as much or more work would be done in the conducting wire as in the lamp. The only way of avoiding this waste of energy without abandoning the idea of small units of light would be either to employ enormously thick conductors or have a very limited area supplied from one works.

I think the difficulty is capable of being sur-
mounted in this way—instead of grouping the 12772
lamps, as Mr. Edison proposes, each lamp being as it were a loop or bridge between two mains, I propose to string them in series, 10, 50 or perhaps 100 lamps being all interposed in one and the same line. In this way every lamp would add to the resistance of the line instead of, as in Mr. Edison's plan, diminishing its resistance. The waste of energy in the conducting wire would thus be avoided.

A copper wire, less than one-eighth of an inch thick, would supply current for one such series of, say, from 10 to 100 lamps, 12773 at five miles distance, with a very small percentage of loss; while to supply at the same distance a corresponding series on Mr. Edison's plan would demand copper conductors of such thickness as would certainly make the plan far too expensive, or, if such thick conductor was not used, there would be an impracticably extravagant waste of energy in the wire. If even 50 per cent. of the energy were expended in the wire, the size of the conductor required to transmit the current, say, even two miles, would be far too great."

12774

I might quote further from Mr. Swan, as he gave an address before the British Association for the Advancement of Science, at the York meeting, from which I have already quoted in my answer to question 8; but as this address was not given until 1881, it does not come within the limit of your question.

I am satisfied that while some electricians and scientific men, prior to 1880, adopted the fallacy to
12775 which you have referred, and while their opinions were to a greater or less extent based upon this fallacy, they, as well as those electricians who did not adopt this fallacy, based the opinions which they expressed with regard to the difficulty or impossibility of subdividing the electric light (using this expression in its broadest sense) upon many other considerations.

They were all familiar with Ohm's law, and they realized that there is an inevitable loss of energy in
12776 the wire which carries the current, which increased with the distance traversed, and which can only be met by increasing the size of the conductors. A difficulty clearly foreseen at that time was, therefore, the excessive cost of conductors for distributing the current. Another difficulty which was much discussed in the parliamentary investigation was the supposed necessity of switching in an equivalent resistance whenever a consumer desired to extinguish one or more lamps, thus making the expense just as great when the lamps were not in

use as when employed for lighting. There were 12777
other minor difficulties which were discussed, such as the disagreeable color of the light, the nitrous fumes produced in the air, and the disturbing effects of the currents on neighboring telegraph and telephone circuits.

68 x-Q. Which of the scientific men, to whose opinions you have referred, did adopt this fallacy and based their opinions as to the possibility of practically or economically subdividing the electric
light wholly or mainly upon it? 17778

A. Mr. Preece seems to be entirely committed to this fallacy. Professor Morton, as shown by my quotations from his lecture given in my last answer, seems to accept the fallacy in the early part of his lecture, but in the closing paragraphs he evidently doubts its truth. Deacon labors under the fallacy, clearly, and yet, in his answer to question 1050, he evidently thinks that this fallacy is not insurmountable.

12779

"1050 x-Q. With regard to the expense of the electric light, I suppose you would say that, in a general way, all the tendency of modern improvement and investigation is to reduce that expense and to render the electric light cheaper?

"A. I do not think that the concentrated lights will be very much reduced in cost, because I do not see where the diminution of cost is to come from. It cannot be in the machine, because we know that already a very high
efficiency of the machine has been obtained. 12780
It can scarcely be to a very great extent in the lamp; but in the subdivided system I think there will be a very great increase of efficiency."

Cooke appears to labor under the same fallacy. Siemens adopts the fallacy; but in his answer to 259, 260 and 261, which I quoted in my last answer, where Mr. Edison's claims are under discussion, he

12781 seems to base his doubts on Edison's peculiar dynamo, rather than upon the fallacy.

Trant adopts the fallacy, and in his article in "Nature," which is already in evidence, refers to Fontaine's experiments.

Keats does not adopt the fallacy in so many words, but he says that "the light cannot be divided."

These are the only electricians or scientific men, as far as I have been able to ascertain, who appear
12782 to have accepted the fallacy stated in cross-question 66, and to have based their opinions to any extent upon it.

Adjourned to Monday, January 26, 1891, at 11 A. M.

12783 * * * * * *

NEW YORK, January 26, 1891, 11 A. M.

Met pursuant to adjournment.

Present—counsel as before.

CROSS-EXAMINATION OF PROF. CHARLES F. CHANDLER BY MR. CURTIS:

72 x-Q. In your answer to cross-question 57 you
12784 refer, as I understand it, to the testimony of Deacon as containing a statement that it would be difficult or impossible to obviate differences in tension such as are referred to in the patent in suit in different parts of the system due to the resistance of the main conductors, and refer particularly to his answers to questions 992 and 994; do you still think that these answers refer to such differences in tension?

A. I do not.

73 x-Q. Do you find any references to differences 12785
of tension such as are referred to in the patent in suit in any other part of Mr. Deacon's testimony?

A. I do not. Deacon does not seem to have gone beyond the question of subdividing the light; he does not even mention the difficulties of distribution; and, when as in question 994, he mentions distances, he does so in connection with the question of subdivision of light, and not in connection with the loss of tension.

74 x-Q. Referring now to the lecture of Mr. J. W. 12786
Swan, from which you quote in your answer to cross-question 57, do you understand that in this lecture Mr. Swan makes any reference to differences in tension in different parts of the system, such as are referred to in the patent in suit as due to the resistance of the main conductors, except so far as such references are implied in, or are to be inferred from his statements in regard to the waste of energy in the conducting wires?

A. He does not. 12787

* * * * * *

NEW YORK, Monday, February 2, 1891, 2 P. M.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF PROFESSOR CHARLES F. 12788
CHANDLER BY MR. CURTIS, CONTINUED:

94 x-Q. Is it not a fact that the literature of the subject shows that the general conception of the nature of the problem of the subdivision of the electric light, as it was understood prior to 1880, was that it related to the production of any kind of electric lamps having illuminating power about equal to a common gas jet and adapted to like purposes, which should possess such characteristics as

12789 would make it practicable for one generator to
operate a considerable number of them located at
reasonable distances from it, and which at the same
time should be economical, durable and cheap
enough to make them commercially useful, and so
simple and reliable that they could be placed in the
hands of the public to manipulate?

A. The lamp described in the question was un-
doubtedly recognized at that date as one of the
necessary elements of the problem of the subdivision
12790 of the electric light, but at the same time it was
recognized that the problem included as an equally
essential part of the problem a system of distribu-
tion so arranged that no more current would be
called for than was necessary to actuate the
lamps in actual use at any given time, and to
supply a suitable current with such economy in the
cost of conductors as would make the system prac-
ticable, and it is hardly necessary to say that every
electrician realized the fact that the current sent out
12791 must be of such a character as to tension and uni-
formity as to properly actuate the lamps.

95 x-Q. You mean by your last answer to say that the production of such a lamp as is described in the preceding question was not what was generally regarded prior to 1879 or 1880 as the problem of the subdivision of the electric light?

A. I mean to say that that was simply a part of
the problem as it was understood at that time.
12792 Lamps had already been invented which possessed
many, if not all, of the properties mentioned in
question 94, but they never had been carefully tested
over any considerable area with a proper system of
distribution.

96 x-Q. Was the production of such a lamp the most important part of the problem?

A. I cannot say that it was. Lamps had already been invented which might have been found successful if the other elements of the problem had been successfully worked out. Even without considering

the carbon filament lamp of Mr. Edison, for which 12793
he applied for a patent on the 4th of November,
1879, and for which he received on January 27,
1880, Patent No. 223,898, or the lamp of Mr.
Swan, the exact date of which I do not remem-
ber, but think it was brought out about the same
time.

97 x-Q. In your last answer you say, "even with-
out considering the carbon filament lamp," &c.,
did you mean to imply by that that there were
other lamps suitable for the purpose besides those 12794
of Mr. Edison and Mr. Swan, which were known
at that time?

A. I did. I meant to imply that such lamps
as those of Starr (or King) of 1840, of Konn of
1873, of Sawyer & Man of 1878, of Woodward of
1876, Edison's platinum lamp, or even Werder-
mann's lamp of 1878, or the Lane-Fox lamp of
1878, described in his English Patent of October
9, 1879, No. 3988. I do not, of course,
mean to express the opinion that any of these 12795
earlier lamps were as good as those of Edison,
Swan or other inventors of later date, but that
they might and probably would have been used
successfully had not these improved lamps been in-
vented.

98 x-Q. Do you mean to express the opinion that
the lamps referred to in your last answer, or any of
them, were practically useful lamps, or were suita-
ble, or could have been made suitable, without in- 12796
vention, for successful commercial use, with a sys-
tem of distribution such as is described in the patent
in suit?

A. I do, assuming, of course, that no better lamps were brought into competition with them.

99 x-Q. Do you mean your last answer to apply to all of the lamps referred to in your answer to cross-Q. 97?

A. I do.

12797 100 x-Q. All the carbon lamps you refer to in your answer to cross-Q. 97 had, for incandescent conductors, carbon rods of far too low a resistance for any practical use, in multiple arc, had they not?

A. They all contained rods of carbon; and I should think that, as they were presented at the time they were invented, their resistance was too low for successful use in multiple arc. Had they been put into practical use, however, their resist-
12798 ance could have been very considerably increased by reducing the size of the carbons. How far this modification could be carried without involving further invention, I am not prepared to say.

101 x-Q. Could the resistence of such lamps have been increased sufficiently without invention, to have made the lamps suitable for commercial use in a system of distribution such as is described in the patent in suit.

12799 A. I have never seen any of the carbon lamps, except the Werdermann of earlier date than Edison's and I do not feel qualified to answer either yes or no to your question. I have the opinion, however, of an eminent electrician, Professor Morton, to the effect that that these lamps were suitable for use in the system shown and described and claimed in the patent in suit; capable of being so arranged as to have the same candle-power throughout the system. This opinion is ex-
12800 pressed in his answers to cross-questions 100 and 101, in the present suit, printed on page 376 of defendant's record.

102 x-Q. Do you agree with Dr. Morton in this opinion, or disagree with him?

A. I agree with Professor Morton in believing that these lamps could have been adjusted to work successfully in the system shown, described and claimed in the patent in suit. The only doubt in my mind is as to whether the necessary adjustment for the purpose of increasing their resistance

would be regarded by the courts as involving fur- 12801
ther invention.

103 x-Q. If you have any doubt on this point, and do not, as you say in response to cross question 101, feel qualified to say whether or not the resistance of such lamps could have been increased sufficiently without invention to have made the lamp suitable for commercial use in a system of distribution such as is described in the patent in suit, how can you express the opinion stated in your answers to questions 98 and 99? 12802

A. My doubts all relate to what would be regarded by the courts as invention. I do not understand that any one of these carbon lamps was in any way limited as to the minimum size of the carbon rods; and every electrician knew that the smaller the rods were made, the greater would be their resistance. In using them, therefore, with the system of distribution described in the patent in suit, the size of the carbons would be adjusted to the resistance required. My only doubt is as to whether such re- 12803
duction in the size of the carbon rod as would be necessary for the system of the patent in suit would or would not so modify the lamp as to lead the courts to decide that it embodied a new invention.

104 x-Q. I assume from your previous testimony that you hold the opinion that it was Mr. Edison who solved the problem of the subdivision of the electric light, which at one time was regarded as difficult or 12804
impossible of solution. Taking this view of the matter, is it not a fact that the invention described in his incandescent lamp patent, No. 223,898, to which you have already referred, is what constituted the practical solution of the problem of the subdivision of the electric light?

A. Only in part. Edison invented a complete system of domestic electric lighting for large areas. His system includes the improved dynamo, a distributory circuit, a lamp, a meter, pressure wires, 12805 regulating device for the dynamo, safety plugs, junction boxes, etc. I do not think the lamp alone solved the problem of subdividing the electric light. I think the system of distribution was essential to the so-called solution of the problem.

Adjourned to Tuesday, February 3, at 1.30 P. M.

12806 NEW YORK, Tuesday, February 3, 1891, }
1.30 P. M. }

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF PROFESSOR CHARLES F. CHANDLER BY MR. CURTIS CONTINUED:

105 x-Q. Did not the invention described in the Edison Patent 223,898 constitute the principal part
12807 of the practical solution of the problem of subdivision referred to?

A. I do not wish to underestimate the value of the invention described in the patent mentioned. I regard it as one of the most important inventions that has ever been made in electric lighting. At the same time, I am not prepared to admit that it constituted the principal part of the practical solution of the problem of subdivision referred to. I think the problem may be regarded as solved by the
12808 invention of the patent in suit in connection with the lamps previously known.

106 x-Q. Do you still hold the opinion that the invention described in the patent in suit was the most essential feature of the solution of the problem, and that the other matters involved in such solution were of minor importance?

A. I do.

107 x-Q. Is it your opinion that domestic illumination with lights comparable in illuminating power

to ordinary gas jets could have been successfuly in- 12809
troduced by means of the system of distribution described in the patent in suit, with such lamps and other apparatus as were known at the date of the application for the patent?

A. It is.

108 x-Q. Is it your opinion that mere engineering or mechanical skill would have been sufficient for adapting forms of lamps, dynamos and other necessary appliances known at the date of the applica-
tion for the patent in suit, for producing the result 12810
stated in the preceding question in connection with the system of distribution described in the patent in suit?

A. It is.

109 x-Q. In your answer to question 7, you refer to the operation of "large numbers of electric lights" of low candle-power "over large areas," and to sending the current "great distances." What do
you mean in this answer by "large numbers," 12811
"large areas" and "great distances?"

A. I meant such numbers and such distances as would develop the difficulty referred to in the specification by the expressions "drop," "difference in tension," "drop in tension," &c. It would be impossible to specify the exact number of lamps or the exact distance, as they would vary with the condition of the system in each particular case.

110 x-Q. Would the number of lamps and their 12812
distance from the source be comparable to the number of gas jets supplied from a single gas works and their distance from the same, as you understand it?

A. Approximately, yes. Though I think that a single gas works may be made to supply a larger area and a larger number of lamps economically than a single central station.

111 x-Q. Did you mean to state, in your answer

12813 to question 7, what you understood to be the problem referred to in the quotations contained in your answer to question 8, as the subdivision of the electric light?

A. I did.

112 x-Q. Do you understand that it was considered at the date of these various quotations that the problem of subdivision required for its solution that the number of lamps and their distance from a
12814 single source should be comparable to the number of gas jets supplied by a single gas works and their distance from the same?

A. Substantially, yes, with the limitation of my previous answer.

113 x-Q. As a matter of fact was not the standard of success which these various witnesses and writers had in mind very much lower than this? I call your attention to the fact that a considerable number of them refer to six or eight lights as the limit-
12815 ed number, and none of them mention any very much larger number of lamps that could be run successfully from a single generator?

A. These witnesses regarded the problem as very difficult or impossible of solution, and when they mentioned six lamps it was not as a limit to the requirements of the problem, but as a limit to what they believed to be the possibility of solution. They thought six lamps might be run with success from a single dynamo; they did not think that this was
12816 the largest number that it was desirable to run. In fact, some of the witnesses speak of running thousands of lamps. I cannot at this moment refer to any statement in the testimony taken before the Parliamentary Committee, in which any particular number was mentioned. I remember that Dr. Siemens in his inaugural address, published, in 1882, in the "Journal of the Society of Arts," makes estimates for supplying 63,378 lights for the Parish of St. James, in London, at the rate of twelve lamps per house. The whole point of this discus-

sion before the Parliamentary Committee was the 12817
problem of replacing gas lighting for domestic purposes by electric lighting. The system of electric lighting by small numbers of arc lamps or Jablochkoff candles of very high illuminating power had already been perfected, and the remaining problem of "dividing the electric light" embodied such a modification of the system as would substitute for the few lamps of high illuminating power many lamps of low illuminating power.

114 x-Q. Would it not have been regarded, prior 12818
to November, 1879, as a satisfactory solution of the problem of subdividing the electric light, if quite a small number of lamps, each about equal to a gas jet, and having the requisite durability, simplicity and cheapness, could have been run by one generator with reasonable economy when distributed over a limited area, as, for instance, if such a number of lights, each of a power equal to a gas jet, as would be required to light an ordinary sized build- 12819
ing or factory, say 50 or 100 lights, located throughout such a building, could be supplied from a dynamo located in the basement or L of such building?

A. This would have undoubtedly been regarded as a great step in advance, but I do not think it would have been regarded as a satisfactory solution of the problem of subdividing the electric light, and making it valuable as a substitute for illuminating gas for domestic purposes. No system would 12820
be a practical success for domestic purposes which required a dynamo in each house.

115 x-Q. Would it not have been deemed a satisfactory solution of the problem of subdividing the electric light, as that problem was understood prior to November, 1879?

A. I do not think it would.

Adjourned to Wednesday, February 4th, 1891, at 11 A. M.

12821 NEW YORK, Wednesday, Feburary 4, 1891, 11 A. M.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF PROFESSOR CHARLES F. CHANDLER BY MR. CURTIS CONTINUED:

116 x-Q. Would you desire to make any change in your answers to cross-questions 107, 108 if the time referred to had been stated as prior to Novem-
12822 ber, 1879, instead of the date of the application for the patent in suit?

A. I should not.

117 x-Q. Did you understand that domestic illumination under the conditions mentioned in those questions would involve a supply of a considerable number of lamps distributed over a considerable area from a single source?

A. I did.

12823 118 x-Q. In your answer to cross-question 97 you refer to Edison's platinum lamp. As I remember, Mr. Edison took out a considerable number of patents for platinum lamps of different kinds. Which one of these did you refer to?

A. I referred to the platinum lamps of Edison which are pictured and described in the "New York Herald" of December 21st, 1879, which have been already offered in evidence in this case: Figs. 1, 2 and 6. Also Figs. 2 and 7 in the article by
12824 Mr. Upton published in "Scribner's Monthly" for February 1880, which has been offered in evidence.

119 x-Q. The Lane-Fox lamp referred to in the same answer also has a burner made of a long length of fine platinum and iridium wire, has it not?

A. It has.

120 x-Q. Would such lamps as the Edison platinum lamp and the Lane-Fox lamp referred to be, in your opinion, such lamps as could have been successfully

used for the practical introduction, commercially, 12825
of domestic illumination with lights comparable in illuminating power to ordinary gas jets by means of the system of distribution described in the patent in suit, if no better lamps had been produced?

A. I think they would.

121 x-Q. Is the lamp described in the Edison Patent No. 227,229 one of the forms of Edison platinum lamps referred to in your answer to cross- 12826
question 118?

A. It is.

122 x Q. In your answer to question 8 you referred to the statements of various witnesses examined before the parliamentary commission and to the statements of various writers on electric lighting, as suggesting or advocating the use of parallel series or multiple series of arrangements of lamps, where the current is to be conveyed to considerable 12827
distances from the station or generator. As a matter of fact, have not these arrangements of circuit been used very largely in modern incandescent lighting since that time, and are they not still largely used?

A. They have been largely used and are still largely used.

123 x Q. The arrangement of circuits used in the defendants' Trenton plant is a multiple series ar- 12828
rangement, is it not; that is to say, there are two lamps connected in series between the main conductors from the dynamos. In each case these pairs of lamps so connected in series are connected in parallel to the main conductors?

A. That appears to be the case from the diagram and the testimony of Mr. Stieringer.

124 x-Q. In your answer to question 4 you refer to your having visited the Thirty-ninth street station of the Edison Company. Is it not a fact that the

12829 so-called three-wire system of distribution is used at that station?

A It is.

125 x Q. That system is a modification of the multiple series system also, is it not?

A. I think it might be called so.

* * * * *

12830 NEW YORK, March 4, 1891, 11 A. M.

Met pursuant to adjournment.

Present—Counsel as before, as to defendant; SAMUEL F. BETTS, ESQ., for complainant.

Adjourned to 1.30 P. M. same day.

1.30 P. M., met pursuant to adjournment.

12831 CROSS-EXAMINATION OF PROFESSOR CHARLES F. CHANDLER CONTINUED:

202 x-Q. In your answer to question 17, you say that in plants involving the use of only a small number of lights and short distances to be traversed there would be no difficulty in providing conductors which would supply the current to all the lamps near and remote, without involving such a drop in potential as would interfere either with the durability or usefulness of the lamp. Do you mean by
12832 this that providing such conductors would not have involved any difficulty prior to the application for the patent in suit, on the part of a constructor or electrician who was skilled in the art as it existed at that time?

A. I mean that the difficulty which it is the object of the patent in suit to overcome would not have been met in small plants, either before or after the date of the application for the patent. Those difficulties are due to the large areas and large numbers of lamps to be supplied.

203 x Q. Do you think it would have involved any difficulty, prior to the application for the patent in suit, to make the conductors of such a size as to secure the results indicated in your answer to question 17, in such a plant as is there referred to, assuming the constructor or electrician to be skilled in the art as it stood at that time? 12833

A. It would not have involved any difficulty to construct a small plant with a few lights, as the difficulties due to distance and large numbers of lights would not be encountered. 12834

204 x-Q. Is not that the way in which such a constructor would have naturally constructed any multiple arc plant, for incandescent lighting of any size, up to the point where the difficulty due to the cost of the conductors of sufficient size for supplying an increased number of lights, or lights located at a greater distance from the generator, began to manifest itself?

A. I think it is. 12835

* * * * * *

NEW YORK, March 9, 1891, 2 P. M.

Met pursuant to adjournment.

Present—Counsel as before.

CROSS-EXAMINATION OF PROFESSOR CHARLES F. CHANDLER CONTINUED:

245 x-Q. Please consider the unfortunate person to whom you refer to be the person skilled in the art not wholly unknown to the law, that he was familiar with what was known in the early part of 1880, say prior to June of that year, in regard to electricity, electrical distribution and electric lighting; that he was skilled in the construction and operation of such electric lamps and electric light apparatue as were then known, and that he knew what had been done publicly in this country prior to that time; knew all that had been 12836

12837 patented and all that had been published with regard to electric lighting and electrical distribution in this country or in foreign countries prior to that time. Do you think that if such a person had been required to make use of the arrangement of circuits described in the Khotinsky patent for lightning an ordinary building, with fifty or one hundred incandescent lamps, such as are referred to in cross-question 242, located in the same building and in the immediate neighborhood of the lamps, he would
12838 have been unable to do so in such a manner as to make the system operate properly?

> Objected to as not limited to the state of the art as shown in the proofs in this case, and therefore as indefinite.

A. I think such an omniscient person might have solved the problem successfully.

246 x-Q. Don't you think that such a person
12839 would have made such a plant operate properly, so far as securing equality of tension at the different lamps is concerned, if he had displayed good skill and judgment in applying existing knowledge in the construction of the plant?

A. I should think he might have done so.

247 x-Q. Don't you think he would have done so?

A. I think he would.

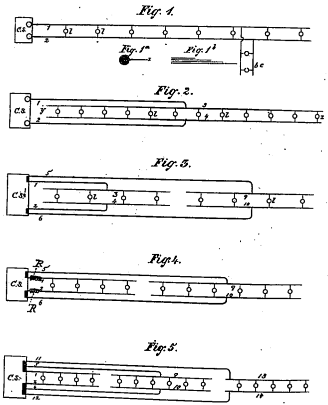
12840

(No Model.) 3 Sheets—Sheet 1.

T. A. EDISON.

ELECTRIC DISTRIBUTION AND TRANSLATION SYSTEM.

No. 264,642. Patented Sept. 19, 1882.



Witnesses:
H. W. Howard
James A. Payne.

Inventor.
T. A. Edison
per Dyer & Wilber
Attorneys.

(No Model.) 3 Sheets—Sheet 2.

T. A. EDISON.

ELECTRIC DISTRIBUTION AND TRANSLATION SYSTEM.

No. 264,642. Patented Sept. 19, 1882.

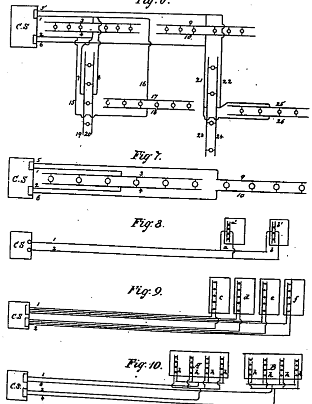
Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.



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Attorneys.

(No Model.) 3 Sheets—Sheet 3.

T. A. EDISON.

ELECTRIC DISTRIBUTION AND TRANSLATION SYSTEM.

No. 264,642. Patented Sept. 19, 1882.

Fig. 11.

Fig. 12.

Witnesses:
[signature] Clark.
N. A. Clark

Inventor:
Thomas A. Edison,
By Rich'd N. Dyer,
Attorney.

UNITED STATES PATENT OFFICE.

THOMAS A. EDISON, OF MENLO PARK, NEW JERSEY, ASSIGNOR TO THE EDISON ELECTRIC LIGHT COMPANY, OF NEW YORK, N. Y.

ELECTRIC DISTRIBUTION AND TRANSLATION SYSTEM.

SPECIFICATION forming part of Letters Patent No. 264,642, dated September 19, 1882.

Application filed August 9, 1880. (No model.) Patented in England September 24, 1880, No. 3,880; in Canada November 15, 1880, No. 11,997; in Italy November 19, 1880; in Belgium November 30, 1880, No. 53,018; in France January 3, 1881, No. 139,588; in Victoria January 4, 1881, No. 2,944; in Austria February 3, 1881; in New South Wales March 7, 1881; in New Zealand March 7, 1881, No. 512; in Queensland March 9, 1881; in Spain April 2, 1881, and in India July 20, 1881, No. 528.

To all whom it may concern:

Be it known that I, THOMAS A. EDISON, of Menlo Park, in the county of Middlesex and State of New Jersey, have invented a new and useful Electric Distribution and Translation System, (Case No. 236;) and I do hereby declare that the following is a full and exact description of the same, reference being had to the accompanying drawings, and to the letters of reference marked thereon.

This invention relates to a method of equalizing the tension or "pressure" of the current through an entire system of electric-lighting or other translation of electric force, preventing what is ordinarily known as a "drop" in those portions of the system the more remote from the central station, and also to other features in systems for the utilization of electricity, as hereinafter explained.

As is well known from patents already granted me and prior applications pending, I use in my system an electric light formed of a continuous incandescing conductor, large numbers of which are grouped into one system, supplied and regulated from a central station, main conductors leading from and to the central station; each lamp or translating device being in a derived circuit to the main conductors, the entire system being what is known as a "multiple-arc" system. From a central station the main conductors may proceed, and it is intended that they should, to a great distance and supply a large number of translating devices. In such cases there is inevitably a difference in tension between various parts of the circuit, due to the resistance of the main conductors. This may be partially remedied by making the conductors very large near or at the station, gradually decreasing their size or conducting capacity; but such plan only lessens slightly the ratio of fall. To obviate the difficulty I provide feeding-conductors, which extend from the generator or generators to the main conductors of the lamp or consumption circuit or circuits, such feeding-conductors not having any translating devices connected therewith, and being connected with the main conductors of the consumption circuit or circuits at the center, ends, or other points on such main conductors. From a central station several sets of such feeding-conductors may run, each set feeding into its own lamp or consumption-circuit or all the sets feeding into a connected system of lamp or consumption circuits. It will be seen that the drop upon the feeding-conductors has no effect upon the relative candle-power of the lamps of the system, the relative candle-power of the lamps being affected only by the drop upon the main conductors of the consumption circuit or circuits between the end of a set of feeding-conductors and points most distant from any feeding-conductors. In order to maintain practically the same candle-power throughout the system, the main conductors of the consumption circuit or circuits should be so proportioned that the drop in tension upon them shall not exceed a definite small limit—for example, five per cent. This drop will make a difference of less than a candle-power in all the sixteen-candle-power lamps of the system, which difference is not perceptible to the eye. Upon the feeding-conductors, however, any loss can be made. This loss will be varied according to localities and the relative cost of copper for conducting purposes and horse-power for generation. This loss upon the feeding-conductors in large and extended systems will generally be greater than upon the main conductors of the consumption circuit or circuits. It may be, for example, about fifteen per cent.; but circumstances might make it desirable to diminish the loss upon the feeding-conductors down even as low as that upon the main conductors of the consumption circuit or circuits, or to increase the loss upon the feeders to more than fifteen per cent.

In this connection I wish to state that I am aware of the French patent of Khotinsky, No. 107,307, granted March 19, 1875.

When it is desired to use a few lamps near the central station they may be placed upon a direct circuit therefrom, with resistance at the commencement or home end of the circuit sufficient to then reduce the tension of the current in such circuit so that it shall only be equal to that in the more distant circuits, and one or more of such circuits may be combined with the circuits before described. When large buildings or blocks of buildings using many lamps are to be supplied, it may be desirable to lay therefor separate feeders insulated from each other.

Where several central stations are used in a city, each having feeding-conductors leading to lamp-circuit conductors of the description before noted, it may be advisable to connect the feeding-circuits of all the stations, equalizing the tension or pressure throughout the entire system of the place where the central stations are located.

In the drawings are given diagrammatic representations of circuits, which will be more fully hereinafter described.

Figure 1 illustrates a plan wherein the conductors are made larger at their home ends, gradually tapering to the outer end of the system. Where such plan is used it is preferable to make the conductor a compound one, composed of several single wires of different lengths, one or two of which extend the whole length of the conductor, others ending at various points, as shown in Fig. 1[b]. These wires are not insulated, but merely grouped in a bunch, which have transverse fastenings at intervals, or which may be fastened together by branch conductors passing around where connections are formed, as shown in Fig. 1[a]. It is preferable to form all conductors which vary in size, decreasing from some point in this manner, and it is to be understood in subsequent descriptions that all such conductors are so made.

In Fig. 2 feeding-conductors 1 2 lead from central station C S, connecting with the lamp-circuit 3 4 at about its center, the conductors of the lamp-circuit being largest at that point, and also of slightly larger capacity at that point than the feeding-conductors. By this arrangement most of the fall of pressure or drop in tension takes place in the feeding-circuit, so that it cannot affect any lamps, while the drop in the lamp-circuit is reduced very low, as before explained, the drop from the center of the lamp-circuit to either terminal being only about one-fourth what the drop would be from y to z if either end were connected directly to the central station. Any desired number of lamp-circuits may be so arranged, each having its proper feeding-conductors, two so arranged being shown in Fig. 3.

In some instances where it is desired to use a few lamps near the station they may be placed directly upon main conductors, and combined with the circuits shown in Figs. 2 and 3, as shown in Fig. 4, where feeders 5 6 connect with lamp-circuit 9 10, arranged as in Figs. 2 and 3, while circuit 1 2, connected directly to C S, has a few lamps upon it, in which case resistances R R should be used therein to lessen the tension of the current in 1 2 to the same extent as it is lessened by the larger conductors 5 6. With such arrangement may also be combined an ordinary terminal circuit containing a few lamps, such as the circuit 13 14 in Fig. 5.

In Fig. 6 is shown direct or main feeding circuits 1 2 and 5 6 with lamp-circuits 3 4 and 9 10 with branch feeders 7 8, 15 16, and 21 22 leading into side streets, supplying lamp-circuits 17 18, 19 20, 23 24, and 25 26, the branch feeders being derived circuits from the main feeders, all constituting a multiple-arc system.

In Fig. 7 feeding-mains 1 2 connect to the center of the lamp-circuit 3 4, while feeders 5 6, leading to a greater distance and to a circuit when comparatively few lamps are required, connects to the end of lamp-circuit 9 10, whose conductors gradually taper from the point of connection. This arrangement is sometimes desirable in sparsely-settled localities, as involving economy in the laying of conductors.

In Fig. 8 is shown feeding-conductors 1 2, from which lead house-feeders a b, which connect to lamp-circuits a' b', which are of same description as circuit 3 4, Fig. 2.

Fig. 9 shows a series of houses or buildings, c d e f, to each of which leads a feeding-circuit of insulated conductor, the lamp-circuit of each house being thereby put in direct connection with the central station C S, the tension of the current in any one lamp-circuit not being affected by the others.

In Fig. 10 are two blocks of buildings, A and B, composed each of several houses, h h h, separate feeding-circuits 1 2 and 3 4 leading to branch feeding-circuits, from which lamp-circuits lead into each house, each house or lamp-circuit being provided with its own connection and meter.

In the arrangements shown in Figs. 8, 9, and 10 the greatest portion of the fall or drop occurs in the conductors leading to the house or block lamp-circuits, the tension or pressure in the branches leading into the houses being maintained practically uniform thereby in each lamp-circuit.

Fig. 11 shows a series of central stations, C S, from each of which lead main feeding-circuits M, which may be of any desired number, each connecting to and feeding into a lamp-circuit, l c. The mains of all the stations are connected by conductors n n n, so that all the stations are electrically connected into one general system, whereby the pressure throughout the entire system is equalized.

In Fig. 12 the lamp-circuit L C is fed by a number of feeding-circuits, connecting thereto on opposite sides, alternately 1 2, 3 4, and 5 6, forming three feeding-circuits, by which arrangement a comparatively uniform force or pressure may be maintained throughout the entire system.

I do not claim broadly a conductor tapering from the source of energy, as such, *per se*, is old; but I do claim, as hereinafter set forth, my particular way of forming such a conductor.

What I claim is—

1. A consumption-circuit, in the main conductors of which the drop in tension is not sufficient to vary practically the candle-power of the lamps connected therewith, in combination with feeding-conductors connecting the consumption-circuit with the source of electrical energy, and having no translating devices connected therewith, the drop in tension upon such feeding-conductors not affecting the relative candle-power of the lamps of the consumption-circuit, substantially as set forth.

2. A consumption-circuit in the main conductors of which there is a definite small drop in tension not sufficient to vary practically the candle-power of the lamps connected therewith, in combination with feeding-conductors connecting the consumption-circuit with the source of electrical energy, and having no translating devices connected therewith, the loss upon such feeding-conductors being greater than upon the main conductors of the consumption-circuit, substantially as set forth.

3. The combination of a consumption-circuit, in the main conductors of which the drop in tension is not sufficient to vary practically the candle-power of the lamps connected therewith, with a feeding-circuit having no translating devices, and extending from the source of electrical energy to the center of the consumption-circuit, substantially as set forth.

4. The combination of two or more central stations having feeding-conductors, and consumption-circuits supplied by such feeding-conductors, as described, of connections between the conductors of the central stations, substantially as and for the purposes set forth.

5. The combination, in one system, of a main circuit connected directly to a source of energy, and containing translating devices, and provided with resistances for lessening the tension or pressure of the current to that of the average of the system, a circuit not directly connected to the source of energy containing translating devices, and a feeding-circuit connecting the latter circuit with the source of energy, substantially as set forth.

6. The combination of a number of uninsulated wires of different lengths grouped together and fastened at intervals, forming a gradually-tapering conductor, substantially as set forth.

This specification signed and witnessed this 4th day of August, 1880.

THOS. A. EDISON.

Witnesses:
WM. CARMAN,
OTTO A. MOSES.

Complainant's Exhibit, Deposition of Sir William Thomson. 12853

UNITED STATES CIRCUIT COURT,

DISTRICT OF NEW JERSEY.

THE EDISON ELECTRIC LIGHT COMPANY vs. WESTINGHOUSE, CHURCH, KERR & COMPANY	In Equity. 12854

JANUARY 5th, 1891, 11 A. M.

Met pursuant to written notices of taking the testimony of Sir William Thomson under the commission issued to the United States Consul at Glasgow, Scotland. 12855

Copies of said notices served upon defendants' solicitors, Messrs. Kerr and Curtis, with admission of service thereon filed with the Commissioner and annexed to this deposition.

Present—SAMUEL R. BETTS, Esq., counsel for complainant, and CHARLES A. TERRY, Esq., counsel for defendant.

Deposition of witness, produced, sworn and examined 12856
the fifth day of January, in the year one thousand eight hundred and ninety-one, under and by virtue of a commission issued out of the United States Circuit Court, District of New Jersey, in a certain cause therein depending and at issue between Edison Electric Light Company, plaintiff, vs. Westinghouse, Church, Kerr & Company, defendants, as follows:

Sir WILLIAM THOMSON, Knight, of the University of Glasgow, Professor of Natural Philosophy in the Uni-

12857 versity of Glasgow, aged 66 years and upwards, being duly and publicly sworn pursuant to the directions hereto annexed, and examined on the part of the plaintiff, doth depose and say, as follows:

1 Q. What is your name, age, residence and occupation?

A. My name is William Thomson; age, 66; residence, the University of Glasgow; professor of natural philosophy in the university. I have been professor
12858 of natural philosophy in that institution for 44 years.

2 Q. What attention have you given to electrical science, and how long have you been familiar with the same? Are you connected with any scientific bodies whose purpose is the advancement of electrical science, and, if so, in what capacity, and have you held any office therein? Have you written or published any article or articles, or treatise or treatises upon the subject of electricity, and if so, what? Have you been accustomed to give instruction upon the subject of
12859 electricity and its practical applications, and if so, for how long and in what capacity? State fully and in detail all facts tending to inform the Court as to your qualifications as a practical and scientific electrician?

A. I have given much attention to electrical science for the last 50 years. About 50 years ago I wrote a paper on the mathematical theory of electricity, which was published in 1842 in the "Cambridge Mathematical Journal," and republished nearly 20 years ago in a large octavo volume containing a collection of my pre-
12860 viously published papers on electro-statics and magnetism. I have written many papers on other branches of electrical science and particularly its practical applications to telegraphy, electric motors, electro-metallurgy, electric transmission of power and electric lighting. These papers have been published in various journals, and many of them republished in three volumes of my collected mathematical and physical papers during the last 15 years. I am a fellow of the Royal Societies of London and Edinburgh, a member of the Institution of Civil Engineers,

and of the Institution of Electrical Engineers. I have 12861
been twice president of the Royal Society of Edinburgh and of the Institution of Electrical Engineers (or Society of Telegraph Engineers). I served for several years on the Council of the Institution of Civil Engineers; I am at present president of the Royal Society at London; I am one of the eight foreign associates of the French Academy of Sciences; I am an honorary member of the American Institute of Electrical Engineers and of many other scientific societies in America and Europe having for their purpose the advancement 12862
of electrical science.

I have regularly given instruction in electrical science and its practical application since 1846, in my public lectures and in my physical laboratory in the University of Glasgow.

During the years 1856-57-58 I was one of the directors of the Atlantic Telegraph Company, and was at sea on the experimental expedition to the Bay of Biscay in 1857, to test the possibility of laying and lifting telegraphic cables in deep water. I was on board H. M. S. 12863
"Agamemnon," taking charge of all the electrical arrangement during the laying of the cable from Valencia, in Ireland, to Trinity Bay, Newfoundland, in 1858; my signalling instruments were used during the short time of the successful working of that cable. They were brought into use again on the two permanently successful cables of 1866, and have been continued in use on these cables and have been regularly used on all great submarine cables ever since. I was consulting electrician to the French Atlantic cable of 1868, and I have 12864
acted as electrician and engineer for all the Atlantic cables since laid by Messrs. Siemens.

My signalling instruments included a marine galvanometer, an entirely new form of electric measuring instrument, which was used first at sea on board the U. S. frigate "Niagara" and H. M. S. "Agamemnon," in the Bay of Biscay in 1857. It was of my invention and it has been used to my knowledge in every Atlantic cable expedition since 1857, and in all the cable work

12865 of the Eastern Telegraph Company. My signaling instruments included also a recorder for giving in a permanent curve or ribbon paper the signals received through a submarine cable. They included also a form of mirror galvanometer used for receiving signals without recording them. This instrument has been largely used ever since I first patented it in 1858, for electric cable testing in factories, for every kind of electric measurement in laboratories, and very especially for the measurement of the electric conductivity of copper,
12866 whether for submarine cables or land telegraph wires or for electric lighting.

I first pointed out in 1858 that different specimens of copper wire, rod and sheet supplied by the maker as of the best quality, and previously believed by all practical engineers to be equally good conductors of electricity did, in reality, differ so much that some conducted only forty per cent. as well as others. I instituted a system of testing all samples of copper supplied to the electric cable factory, according to which
12867 all which fell short of the best by more than three or four per cent. were rejected. This system has been in use ever since, and the manufacturers of copper wire, rod and sheet have adopted the system of testing for electric conductivity to such good effect that when supplies of copper came to be demanded for electric lighting they were readily obtained at prices little exceeding those of ordinary bar copper.

I have acted as consulting electrician for the original Swan Electric Lamp Company of Newcastle, England,
12868 and I am at present consulting engineer to the National Telephone Company, to the Metropolitan Electric Supply Company of London, to the Electric Construction Corporation of England, to the Westminster Electric Supply Company, to the International Okonite Company of England, to the Kelvinside Electric Lighting Company of Glasgow, and to the Electric Lighting Company of Mavar and Coulson of Glasgow.

3 Q. Have you given any special attention to the subject of electric lighting, and, if so, for how long?

A. Yes, much attention ever since about the year 12869
1870, when varied practical usefulness seemed probable for the electric arc light. I was intimately acquainted with the late Sir William Siemens, and heard much from him of his own great work in dynamos, and their application to the electric arc light, and the electric transmission of power. In 1881 I got from his works a shunt dynamo, the first that was made except for experimental purposes in their works, and applied it to the electric lighting of my lecture room, laboratory and house by incandescent lamps. From that time till now 12870
I have been continually occupied with electric lighting, both in my own establishment and in advising public companies and others. I have devoted myself much to designing and constructing instruments for the electric measurement required for practical work in electric lighting. I have invented and patented many instruments for this purpose, including ampere meters to measure currents of from less than half an ampere to ten thousand amperes, and volt meters to measure electric pressures of from less than one volt to one hun- 12871
dred thousand volts; also an electric supply meter and a marine volt-meter; all these instruments are in practical use. As early as 1859 I introduced into England the system of absolute electric measurement initiated in Germany by Gauss and Weber, and through the cooperation of a committee of the British Association appointed about 1860 I succeeded in obtaining the general acceptance of this system in England. I was a member of the Paris Congresses by which within the last ten years it has become generally adopted by en- 12872
gineers and scientific men in all parts of the world, and the names Ampere, Volt, Ohm, etc., have been given with universal acquiescence to the several fundamental units found convenient for the practical use of the system.

4 Q. Were you, in and prior to the year 1880, familiar with the condition of the science of electric lighting in Great Britain, and with the various apparatus which have been described or proposed or used up to that

12873 time for the purpose of electric lighting, and if so, how did you become so familiar?

The question objected to as irrelevant and immaterial.

A. Yes; in and prior to the year 1880 I was familiar with the condition of the science of electric lighting in Great Britain, and with the most important of the various apparatus which have been described or pro-
12874 posed or used up to that time for the purpose of electric lighting. I became familiar both by seeing, I believe, all the really important apparatus in actual use and by reading on the subject in scientific journals. I also learned much from continual intercourse with engineers, electricians and scientific men generally.

I was intimately acquainted with the scientific members, Lord Lindsay and Dr. Lyon Playfair (now Sir Lyon Playfair), of the select committee appointed by Parliament on the 28th of March, 1879, to consider
12875 whether it is desirable to authorize municipal corporations or other local authorities to adopt any scheme for lighting by electricity, and to consider how far, and under what conditions, if at all, gas or other public companies should be authorized to supply light by electricity. From the evidence given before that commission I learned much of the most recent proposals for electric lighting by the most able engineers up to that time. I made a study of the whole subject up to that period for the purpose of giving evidence which I
12876 was invited to give, and gave before that committee.

5 Q. Are you familiar with the ordinary modes and methods practiced for many years past and prior to 1880 in the distribution of gas from gas-holders, and water from reservoirs, in and throughout towns and cities, and with the methods in use for approximately, or as far as possible, equalizing pressures in such systems?

Objected to as immaterial and irrelevant.

A. I am quite familiar with the principle of all these 12877
modes and methods. I have made very particular study of hydraulics generally and of the flow of liquids and of gases through tubes of all diameters, from capillary tubes up to the largest pipes used for gas and water mains.

I have myself made many laboratory experiments on the subject, and have published many articles relating to it, some of which are contained in my three published volumes of collected papers, and others are to be found in the proceedings of the Royal Society of Edin- 12878
burgh, the Transactions of the same society, and the "Philosophical Magazine." I am familiar with the methods in use for approximately, or as far as possible, equalizing pressures in such systems, and was so familiar prior to 1880.

6 Q. Have you read, and do you understand, copies of the following patents:

British Patent of Richard-Werdermann, No. 2477 of 1878; British Patent of St. George Lane-Fox, No. 3988 of 1878, and No. 4636 of 1878; French Patent of 12879
Khotinsky, No. 107,307, March 19th, 1875?

And also of the following publications:

"Napier's Electro Metallurgy," published in 1867, page 955; a letter from St. George Lane-Fox, entitled "Electric Lighting," published in "London Times" of December 26, 1878; "Practical Treatise on the Manufacture and Distribution of Coal Gas," by Samuel Clegg, Jr., published in London, 1841, pages 166-174; "Treatise on Pressure of Illuminating Gas and the Means to be Employed for Regulating 12880
It," by H. Giroud, published in Paris, 1867, pages 1 to 11, 50 to 80, 116 to 137, and same work of the same author, edition of 1872, pages 9 to 15, 26 to 28, 40 to 49; paper entitled "Societe Technique de L'Industrie du Gas en France," Paris, 1879, pages 134 to 136, containing a paper on Pressure in a System of Pipes, by F. Allavoine; "The Telegraphic Journal and Electrical Review," published in London in 1878, volume 6, pages 455-458; articles entitled "The Werdermann Electric Light," also article entitled "La Lumiere

12881 Werdemann," published in "L'Electricite," volume 1, pages 265 to 268, at Paris?

A. I have read all these patents and articles referred to in the above question as given in the defendant's printed record in this case, and understand the same.

7 Q. You have said in answer to question 6 that you have read the patents and articles mentioned therein and understand the same; now please state whether you were familiar with the same, or otherwise possessed the information or substantially the information
12882 contained therein on the subject of electric lighting and on the distribution of electricity, water and gas, as early as the years 1879 and 1880, and if you were not familiar with any of such matters at that date, please specify with what you were then not familiar?

Objected to as irrelevant and immaterial.

A. I was familiar with Werdermann's Lamp, described in his patent referred to, very soon after its invention.
12883 I certainly saw it in action at Paris in 1881, and I may have read of it as early as 1880, but I am not sure. I read Lane-Fox's letter to the "London Times" at the time it was published, and I knew his patents, referred to, about ten years ago, but I am not sure if I knew them so early as 1880. The French patent of Khotinsky I have only become acquainted with as a patent in connection with the present case, but I was perfectly acquainted with the multiple-arc system of connection for electric lamps as described in his patent, as early as
12884 1879. As early as 1879 I was perfectly familiar with all the principles and practical applications of them described in "Napier's Electro Metallurgy," and in the treatises of Clegg, Giroud and Allovaine referred to in the sixth question. It is most probable that I have read the article, "The Werdermann Electric Light," in the "Telegraphic Journal and Electrical Review," at the time it appeared in 1878. I do not remember reading at the time the French article, "L'Electricite," referred to.

8 Q. Please state whether any commission was appointed by the British Parliament in or about the year 12885
1879 to investigate the subject of electric lighting and the practicability and feasibility of the same, and whether you were one of the witnesses examined before said commission; and whether you were then and now are familiar with the state of scientific opinion at that time, upon the question of the possibility of practically distributing the electric current so as to admit of electric lighting any considerable area with large numbers of incandescent electric or other lamps, and maintaining uniform differences of potential at the terminals of 12886
all such lamps, while using conductors of practically available size, and if so, please state what the opinion of scientific men on that subject was in England at that date.

Objected to as irrelevant, immaterial and incompetent.

A. Yes, a select committee was appointed by the British Parliament on the 28th of March, 1879, as 12887
stated in my answer to question 4, to investigate the subject of electric lighting. I was one of the witnesses examined before that commission. I was then and am now familiar with the state of scientific opinion upon the question of the possibility of practically distributing the electric current for the electric lighting of considerable areas. Incandescent electric lamps were not at that time generally known to be practically available for ordinary electric lighting. No method was known 12888
for maintaining uniform differences of potential at the terminals of whatever lamps might be used. Suggestions were made by myself and other witnesses as to the regulation of electricity for electric lighting, but they had reference rather to regulation for uniform strength of current than for uniform potential, the idea of using arc lamps being then general, if not universal. The object of this commission was to consider whether it is desirable to authorize municipal councils or other local authorities to adopt schemes for lighting

12889 by electricity, and whether gas or other public companies should be authorized to supply light by electricity. All the best known engineers and scientific men of England who had studied electric lighting theoretically or practically, and many from France and Germany, also gave evidence. The chief practical gas engineers of England also gave evidence. The question of using the electric light at various distances, great or small, from the place of supply, was brought prominently before the commission. The subject of drop of tension
12890 was scarcely referred to.

The general idea was to provide uniform current through a series of arc lamps in circuit, and to provide for uniformity of current in the event of one lamp or more being cut out of the circuit. I myself pointed out that this might be done by inventions not then made according to which a governor for the dynamo might be provided, which, when one of the lights is perfectly short-circuited, would not give more current than is wanted for the other light or
12891 lights, whether in the same circuit or in parallel circuits (see my answer to question 1,849, on page 187 of the printed report of the Commission). No light whatever was thrown by any of the witnesses, whether gas engineers or electric engineers, or scientific men not engineers, on the question of maintaining uniform differences of potential at the terminals of all lamps used for the electric lighting of any considerable area, whether distant from or near to the source of supply.

12892 9 Q. Are you familiar with the system of electric distribution for electric lighting with incandescent lamps, for lighting large areas or districts with such lamps supplied and regulated from a central station, as practiced by companies or individuals under the Edison patents, and if so, how long have you been so familiar with such system?

Objected to as immaterial, irrelevant and incompetent.

A. Yes; since 1881. At that time I set up an in- 12893
stallation for the lighting of my laboratory, lecture room, and house, at the University of Glasgow, in which I used Edison lamps in some parts and Swan lamps in others, all being incandescent lamps. I used the Edison system of multiple arc, which I believed then, and still believe, to have been originated by him as described in his Patent No. 369,280 for the use of incandescent lamps. I did not at that time know his feeder system, and I felt considerable inconvenience in consequence. When sufficient power was given in the 12894
source to produce the proper potential or pressure in my house, lamps in my lecture room and laboratory were exposed to too great pressure, and their lives were thereby shortened. And when the pressure or potential at the source was reduced so as to be suitable for the laboratory or lecture room lamps, the lamps in my house were dull on account of insufficient pressure. The inconvenience was, however, not serious, because I scarcely ever had more than quite a small number of lamps lighted in my house at times when 12895
my laboratory or lecture room was lighted; I have, therefore, not thought it worth while to amend my installation after having learned the feeder system from Edison, though I saw perfectly how the inconvenience, such as it was, would be perfectly cured by introduction of the feeder system.

So far as I can recollect, my first knowledge of the feeder system was when I first saw it in the Pearl street station, in New York, in 1884.

I saw a very excellent use of the feeder system in a 12896
large jute spinning mill, in Dundee, in the year 1887–'88. I was asked by the proprietor to report on the installation. It consisted of four consumption circuits at different distances from the engine and dynamo supplying the current. Each of these consumption circuits was supplied by a pair of conductors, forming a feeder coming away from the supply source all together, but all insulated from one another, exactly as represented in figure 9 of Edison Patent 264,642.

10 Q. You have stated, in answer to question 9, that

12897 you are familiar with the system of electric distribution, as referred to therein and practiced under the Edison patents. Now, please state whether you know of the use therein of large numbers of electric lights formed of continuous incandescent conductors, grouped into one system, which system has the following characteristics and method of operation for equalizing the tension or pressure of the current throughout the same, and preventing drop in tension from unfavorably affecting the system: (1) A central station for the
12898 supply and regulation of the electric current to the system; (2) the system one in which the number of lamps and the distance of some of the same is so great that drop in tension is a difficulty which has to be met and avoided; (3) such lamps connected in multiple arc between direct and return conductors, forming mains or consumption circuits; (4) the mains, or consumption circuits, so proportioned as to quantity of conducting material, with relation to the number of lamps connected and the distances of
12899 such lamps from each other, that the drop in tension on such mains is not sufficient to vary practically the relative candle-power of the lamps connected therewith; (5) the mains or consumption circuits fed and regulated from the central station through special conductors or "feeders," with which no current consuming devices are directly connected, and the current-traversing which is under the control of the central station exclusively as to its pressure.

12900 Objected to as immaterial and irrelevant.

A. The Pearl Street Station of New York, when I saw it in 1884 and examined it in great detail, possessed, to the best of my knowledge, all the characteristics referred to in the question.

The electric light installation which I saw in Dundee in 1888, having been designed on consultation with myself in 1887, contained all these characteristics as stated in the question.

11. Q. You have stated in answer to question 10

that you are familiar with systems of electric supply, 12901
distribution and regulation, having the features referred to therein. Please state whether such systems have been introduced into practical use to any considerable extent, and if so, to what extent, and how far the same have been practiced and found to be useful or important?

Objected to as irrelevant and immaterial.

A. Besides the introduction of such systems in New 12902
York, Philadelphia, and other cities of the United States, in which I believe it has been largely used, I know it to be largely used and to have been found exceedingly valuable in England and Scotland. For lighting any considerable district of a city with a direct current system I believe there is no practical alternative to the use of a system having the characteristics described in the tenth question, except the adoption of lamps adapted to different voltages in different parts of the system. This alternative, besides being 12903
very inconvenient in practice, is of comparatively limited application, and, except in comparatively small districts of cities, I believe it could not be adopted with satisfactory results. Unless the method of high pressure alternate current and transformers is adopted in any case for the lighting of a large extent of city, I believe the method of consumption circuits and feeders described in Edison's Patent 264,642 must be used, and will be found a satisfactory solution of the problem of electric lighting through even much larger districts of 12904
cities than those to which it has hitherto been applied.

12 Q. Please state whether, in your opinion, the conception and carrying out in practice of the system of distribution referred to by you in your answer to the 10th interrogatory was, in and during the year 1880, one which would have naturally suggested itself to a person skilled in the art and familiar with the theory and practice of electricity at that day, or was within the ordinary skill of the calling of electricians at that date, if he or they had been required to devise or con-

12905 struct a system for practically distributing electricity for electric lights over a considerable area and with reasonable economy in conductors?

Please give such reasons as occur to you for any opinion that you may express in your answer to this interrogatory?

Objected to as immaterial and irrelevant.

A. In my opinion the system of distribution re-
12906 ferred to in the 10th interrogatory and in my answer to it, was not one which in and during the year 1880 would have naturally suggested itself to a person skilled in the art and familiar with the theory and practice of electricity at that day. I believe that an electrician of that day, if he had been required to devise or construct a system for practically distributing electricity over a considerable area, would not have found it possible to provide sufficiently uniform voltage for all the lights except by using enormously large conductors.
12907 The only way which could have occurred to him, without thoroughly new invention, to keep within reasonable economy in the conductors, would have been to provide a central station with steam engines and dynamos for each such comparatively small districts of consumption as would allow nearly enough uniform voltage to be maintained throughout it, for the good working of the lamps.

Edison's invention of supplying a pair of separate conductors for each such subdivision of a large area to be
12908 lighted solves the problem, but it is a very remarkable invention and one which could not have been suggested to any electrician from what he knew of previous electric science or practice. The subject had in fact been much discussed so far as subdividing the electric light to give numerous small lights suitable for domestic lighting, etc., was concerned; but the special requirements of the incandescent lamp, according to which differences of pressure of more than two or three per cent. would be a considerable evil and source of loss, and difference of ten or fifteen per cent. quite intoler-

able, presented quite a new problem. No other application of electricity previously made had presented any 12909
such requirements; and no combination of dynamos and batteries and electric conductors and translating devices, or any mode of using the electric currents in the conductors previously used in practice, or described in published works so far as I know, had presented any features, the adaptation of which, without thoroughly new invention, could have solved Edison's electric lighting problem.

13 Q. In answering question 12, you referred to "the 12910
special requirements of the incandescent lamp, according to which differences of pressure of more than 2 or 3 per cent. would be a considerable evil and source of loss;" to what type of incandescent lamp do you there refer?

A. I had in my mind the modern Swan-Edison lamp. A lamp of older type, such as the original Edison lamp, and experiencing only something less than a candle-power on a sixteen candle lamp, with 5 per cent. difference on the voltage, would not be seriously 12911
inconvenienced by a difference of 5 per cent. on the voltage in different parts of the consumption circuit. In that case I should consider 5 per cent. of difference of voltage in different parts of the consumption circuit quite allowable.

14 Q. Did any such system of distribution or means of supplying or maintaining equality of tension or pressure throughout a system of electric lighting, as that referred to in the 10th interrogatory and your answer thereto, occur to you, or to your knowledge, to 12912
any of the other electricians who were before the Parliamentary Commission in 1879, as a means of solving, or as tending in any degree to solve, the difficulties incident to the distribution of electricity to large numbers of electric lights, over considerable area, at equal pressures or potentials, and with reasonable economy of conductors; if not, why not?

Objected to as irrelevant, immaterial and incompetent.

12913 A. No such system occurred to myself nor, I believe,
to any of the other electricians who were before the
Parliamentary Commission in 1879. My belief is
founded on personal recollection of what I heard at
meetings of that commission, and in conversations with
many of the persons who gave evidence before it, and
with members of the commission itself. I feel quite
sure that if the persons who gave the evidence had had
the idea of any such system as that referred to in the
present question, he would have made it known. I
12914 find my recollections wholly confirmed by referring to
the printed report of the commission; for example, on
page 47, Mr. Conrad Cooke answers to Lord Lindsay's
question No. 389, "Supposing that the occupier of
one house wished to put out his lights, how would this
be effected? In that case, if you throw out a lamp or
throw out a house, you must throw into the circuit a
resistance exactly equal to what you cut out. If you
do not do that you will affect every lamp in the
series, and the machine as well. If you put out your
12915 lights by breaking the circuit, you put out every light
in the series."

This shows that lamps in series were contemplated,
and the preceding question, 388, shows that incandes-
cence lamps were thought of. In answer to another
question, number 425, page 51, Mr. Cooke said, referring
to Dr. Siemens, who had been named in the question:
"His nephew told me himself that he has seen, I think,
over 200 lamps on one circuit" (of Edison's). "I
must say I should like to see it myself, and that is
12916 all I can say." This clearly proves that Edison's sys-
tem was quite unknown to Mr. Cooke, and that he did
not see how the results alleged to have been obtained
by it could have been obtained.

In answer to question 951, "At the present moment,
in the illumination for public purposes, the lights are
divided into series," Mr. Deacon said, "Yes, in all
cases except one that I have seen. I believe that there
is an American invention divided in multiple arc;"
question 952, "Lord Lindsay," "What system is that,
the Brush system?" Deacon answered, "No, I was

speaking of Edison." In answer to question 1163, Mr. 12917
Woodall said, "I take it that it has been established
that only a limited number of lights can be put upon
one circuit. If you want more lights it would be nec-
essary either to bring a fresh supply into the house, or
to re-arrange that circuit upon which you desired to
put more lights."

The evidence I gave myself referred exclusively to
arc lights, preferably, I believed, arranged in series, and
in my answer to question 1849, to which I have referred
in my answer to question 8 of the present inquiry, and 12918
which was as follows: "Yes, but with proper reg-
ulators, by inventions not yet made, the machine will
have a governor, according to which, when you short-
circuit without resistance any one of the lights, the
machine will not give more current than you want for
the other light or lights, whether in the same circuit or
in parallel circuits."

I had not myself at that time any idea leading
towards the practical realization of any such distribu-
tion of conductors and placing of lights to be supplied 12919
by them as that referred to in the 10th interrogatory,
and the only ideas tending in that direction which
were brought before the parliamentary commission
in 1879 were those which had been suggested by reports
which had come from America of Mr. Edison's work
and inventions. Even as late as 1882, Mr. Swan, who
had by that time brought out in England his incan-
descent lamp, and had very carefully and anxiously
studied the question of distributing electricity for large
numbers of electric lights, in a paper communicated to 12920
the British Association at Southampton, in August
1882, made the following statement: "The only
escape from that limitation (extent of distribution) lay
in having secondary batteries at stations or in houses,
and in these batteries being connected in series and fed
by currents of higher tension; the principle still hold-
ing of multiple arc, not from the central station, but
from the subsidiary ones at which the batteries are
charged. Once imagine the possibility of these second-
ary batteries being kept at a perfectly constant condi-

12921 tion of charge by some automatic arrangement, and we might look to that as a means of escaping from the difficulties of wide distribution."

In his lecture of October, 1880, to the Literary and Philosophical Society of Newcastle, Mr. Swan had said: "The only way of avoiding this waste of energy without abandoning the idea of small units of light would be either to employ enormously thick conductors, or have a very limited area supplied from one source." This was said with reference to Mr. Edison's plain mul-
12922 tiple arc system. The last eight words of this quotation prove that Mr. Swan did not then know of Mr. Edison's feeder system, which had in fact been applied for as a patent in America on the ninth of the preceding August, and was patented in England on the 24th of September, of the same year, 1880.

The quotation I have made from Mr. Swan's communication to the British Association of August 1882, describes a method involving subsidiary consumption circuits, and agreeing in this respect with Edison's in-
12923 invention, but without any explanation as to the feeders, and with a use of secondary batteries which is sometimes adopted at the present day in connection with Edison's feeders and consumption circuits. The fact that a man of inventiveness and high ability like Mr. Swan had realized only as late as 1882 something of the possible practical importance of the subdivision of large areas into consumption circuits all fed from a central station, shows how far from obvious was Edison's solution of the problem, and helps to answer the
12924 last part of the question at present put to me, "If not, why not." Again, towards answering this part of the question I may refer to the inaugural address of Dr. C. W. Siemens before the Society of Arts on the 15th November, 1882, in which he said: "He thought it would be possible to establish electrical mains in the shape of copper rods of great thickness, with branches diverging from them in all directions, though he was himself decidedly adverse to such a plan."

"He would limit the area of a densely populated district to one-quarter of a square mile, notwithstanding

other individuals of high standing in electrical circles 12925
held that areas of from one to four square miles could be worked to advantage."

With regard to the size of conductors Dr. Siemens said: "In considering the proper size of conductors, two principal factors have to be taken into account: first, the charge for interest and depreciation on the original cost of a unit length of the conductor; and, secondly, the cost of the electrical energy lost through the resistance of a unit of length. The sum of these two, which may be regarded as the cost of the convey- 12926
ance of electricity, is clearly least, as Sir William Thomson pointed out some time ago, when the two components are equal. This, then, is the principle on which the size of a conductor should be determined." (Extracted from the "London Electrician" of November 18th, 1882, pages 17-19). There is not a word here of the necessity to secure against too great drop of electric potential between the dynamo and the lamps, or too great differences of drop between the different lamps of the system, and the narrow limitation 12927
of the area insisted upon shows that Dr. Siemens had no idea of Edison's solution of the problem, and thought only of overcoming the difficulty by enormously massive copper conductors with branches diverging from them to the points of consumption. From his earliest commencement as an inventor and engineer, Siemens had been occupied with water and gas. His very first invention was a water-meter, and it is not probable that any one in the years 1879-80 knew better than he did of the difficulties met with in the distribu- 12928
tion of water and gas, and of the methods which had been practically used or proposed for overcoming them.

About that time or a little later one of our first electric engineers, Mr. Crompton, who has in fact been the first to introduce successfully and in a large scale lighting from a central station in London, told me that he was obliged to use larger copper conductors than would be required merely in accordance with my principle for economy, in order to avoid so great a drop in potential

12929 as would be inconsistent with the good working of the lamps. At that time he had no idea of the feeder system, which he has since adopted with marked success in the Kensington-Knightsbridge electric lighting. Siemens' solution was not augmenting the size of the conductors above that calculated from the economic law, but to limit the size of the station supplied. Neither this nor the solution first proposed by Crompton is satisfactory in respect to the practical demands for the electric lighting of towns. Edison's feeder
12930 system is now universally admitted to be satisfactory to a very remarkable degree. I am asked, why did not some one else not invent it. The only answer to this, the last part of the question, I can think of, is that no one else was Edison.

All that portion of the last answer following the words "Edison's work and inventions" and commencing with the words "even as late as 1882," etc. is objected to as irresponsive to any-
12931 thing contained in the question; and objection is also made to all the references to the Edison patent, as being entirely irrelevant to the question, and irresponsive; and further objection is made to those portions of the answer seeking to couple the name of "Edison" with various systems of distribution as being an unwarrantable attempt to laud Mr. Edison.

15 Q. Please state whether, in your opinion, the
12932 analogies known prior to 1880 to exist between the action and flow of ponderable fluids, such as gas and water, and of the so-called electric fluid, were sufficient to teach electricians, or those skilled in the theory or practice of electricity, in and prior to 1880 (or whether the information contained in the publication, of *Clegg*, *Giroud* and *Allavoine*, referred to in interrogatory 6, was sufficient to teach such persons), that electricity could be successfully distributed over considerable areas to incandescent electric lamps, in the manner and by the means referred to in the 10th inter-

rogatory, and your answer thereto, so as to maintain 12933
uniform candle-power through the system? Please give your reasons in detail for any opinion you may express?

Objected to as immaterial and irrelevant.

A. I do not think the analogies known prior to 1880 between the action or flow of gas and water and of electricity, were sufficient to teach electricians that electricity could be successfully distributed over consider- 12934
able areas to incandescent electric lamps in the manner and by the means referred to in the 10th interrogatory, so as to maintain uniform candle-power throughout the system. I have myself for many years, at least thirty-five years, been familiar with the analogies between the flow of gas or water in pipes and electricity in conductors, and have explained and illustrated that analogy in many published works contained in my volume of collected papers mentioned in my answer to interrogatory 2. To make a proper working analogy, 12935
the pipe through which gas or water flows must be filled with porous or spongy material, through which the gas or water would percolate when compelled to do so by difference of pressure at the two ends of the pipe. We should then have flow of the ponderable fluid in simple proportion to the pressure, as is the flow of electricity in a conductor. In reality, the flow of gas or water through a pipe is nearly in proportion to the square root of the difference of pressures, but it is also affected by various other circumstances for which 12936
there is no analogy in the flow of electricity through conductors. Thus, in the defendants' translation of Giroud's treatise (page 615), we find: "Coming from the holder under a pressure which is necessarily constant, in Paris, 150 mm. for example, the flow of gas is obstructed first by the outlet valves at the works, then by the turns or elbows of the pipes, by narrowings of pipes of too small diameter, by differences of level, and finally, by the stopcock of the burner itself; and this obstacle, the last of all, allows the gas to escape from

12937 the orifice of the burner at a pressure of hardly more than two or three mm., and fifteen or twenty, on burners constructed on false principles. It is between these two extremes that all the phenomena of circulation take place which we are about to discuss in this work." This is absolutely unlike the problem of electrical distribution. The object of pressure for gas between the works and the place of consumption is merely to bring the gas to the place. The enormous range of pressure from 150 mm. to two or three for the best burners is
12938 utterly different from anything that occurs in the electric problem. The efficiency of the gas is not dependent on its pressure, but on its combustion, and it is remarkable in contrast to the action of electricity that it gives better results at the low pressure of two or three mm. than at the higher pressure of fifteen or twenty. In the electric light the efficiency of a certain quantity of electricity depends wholly on its pressure, and lamps adapted to work at a pressure of twenty would give with the same quantity of electricity ten times as
12939 much light as lamps of the same quality, adapted to work at a pressure of two.

In an electric system, delivering electricity from the source at a pressure of 150, and using it at a pressure of 3, only $\frac{1}{50}$th of the whole energy would be used, $\frac{49}{50}$th's of it being wasted by the generation of heat in the conductors. The comparison of the flow of electricity in a single conductor and the flow of water or gas in pipes, set forth in the diagram facing page 292 of the defendant's printed record in this case, represents the almost
12940 total loss of energy by the electricity in figure 3, in circumstances analogous to those of the outflow of gas at B in figure 2. The difficulty of making out anything of a quantitative comparison between the two cases is illustrated by the fact that the forces illustrated by the spring balances and repelled discs of figure 3 would be, not in simple proportion to the pressure, but would depend in a very complicated manner on the squares of the pressures and the configurations of the lines of electric force between the discs, and round their edges to the earth. Thus the lower ends of the springs

would be nothing nearly in a straight line, as shown in 12941
figure 3, while the levels of the water in the pressure gauges of figure 2 would, as correctly shown, be essentially in a straight line. The electric system essentially involves two conductors, with a difference of potentials maintained between them. This difference of potentials is what is technically, and by English Board of Trade rule, called "pressure." To this there is absolutely nothing analogous in pipes for the distribution of water or gas. The long-known fact that gas pressure can be, to a rough approximation, equalized through a 12942
consumption district by using a long supply pipe from the gas works, which may be of such small diameter as to give rise to large and varying differences of pressure between its two ends, and taking the whole supply direct from the end of it, remote from the gas works, could not, I think, suggest to the electrician the system of using two feeding conductors, in combination with a supply system such as that referred to in the 10th interrogatory. Even a careful reading of the treatises of Clegg, Giroud and Allavoine, referred to in inter- 12943
rogatory 6, could not have given information that electricity could be successfully distributed over considerable areas to incandescent lamps in the manner and by the means referred to in the 10th interrogatory.

The equalizing of electric pressure within five per cent. in the consumption circuit, in all varying conditions of the lamps used in different parts of the circuit, and the calculation of the conductors required for this purpose and for the feeding conductors, after having 12944
formed the idea of using feeding conductors, is a problem upon which no light whatever is thrown by anything to be found in these treatises. And in fact prior to 1881 none of the engineers who attacked the problem of the electric lighting of cities, many of whom were thoroughly acquainted with gas distribution, did propose or show any signs of having invented the system of consumption district and feeders till Edison gave it in his Patent 264,642. Even as late as 1885 we find Professor George Forbes in his Cantor

12945 Lectures, delivered in the month of February of that year and published in the "Journal of the Society of Arts" for October, 1885, giving an elaborate and full comparison of electric distribution with gas distribution, and describing Mr. Edison's feeder system and patent in the following statement: "It must be acknowledged that the simple tree system, where all the dynamos are connected in parallel with the mains, presents a very serious obstacle in the rapid fall of potential, the maximum distance of a lamp from the station along the
12946 line of conductors, consistent with the economical considerations, being 124 yards if the pressure required for all lamps is the same."

"In the year 1880, Mr. Edison took out a patent in England (No. 3,880), besides other countries, in which he gets over the difficulty by using what he calls feeder mains.

"It is a result which would certainly have been arrived at by any one who thoroughly and intelligently worked out the problem. But, so far as I can dis-
12947 cover, he was the first, by a long time, to hit upon this cure for the evil; and I must say that it is interesting to find how thoroughly he had gone into the problem at that early state of electric lighting, although in a patent of slightly earlier date he describes the tree system as being all that is required for electric lighting, and does not notice the fact of potentials as affecting the problem."

This statement is altogether in accordance with what is proved by the other evidence I have given that Mr.
12948 Edison's feeder method was a new solution of a problem on which many electricians had worked without finding it, and to which a complete knowledge of the analogy between gas distribution and electric distribution had not given information or ideas leading to the solution.

* * * * * *

48 x-Q. Will you please give as full a description as you can of the organization of circuits in the Kensington and Knightsbridge plant?

A. It consists of several pairs of feeders, supplying

several consumption circuits. In many cases the feed- 12949
ers and portions of the consumption circuit are parallel, and all insulated from one another, close side by side in the same trough, in order that the drop of tension between the central station and the ends of the feeder may not add to the negligible drop of tension in the consumption circuit, and so render the difference of pressure between different lamps in the consumption circuit too great to be negligible. The introduction of the appliances necessary to mutually insulate from one
another different portions of the positive conducting 12950
metal and of the negative conducting metal would seem, to a person who did not understand Edison's invention, which forms the subject of the present case, a needless and wasteful complication. As it is, it is a remarkable testimony to the ingenuity and to the practical value of the invention.

* * * * * *

99 x-Q. Were you, as an electrician, aware, prior to 1880, that in order to attain an even distribution of
pressure over a given circuit that the size or conduc- 12951
tivity of the conductor must be taken into consideration?

A. Yes.

100 x-Q. And that with a given number of current consuming devices, connected in parallel or in multiple arc between two conductors supplied with a given difference of potential, that difference of potential could be more nearly equalized throughout the circuit by increasing the size of the conductors?

A. Yes. 12952

101 x-Q. Was it a matter of common knowledge among well-informed electricians?

A. Many very well informed electricians of great inventiveness and much knowledge of electrical instruments and appliances at that time had exceedingly vague and erroneous notions on this subject. Witness Werdermann, talking of "weak currents or currents of low tension." Ohm himself, on whose law all other calculations in this respect are founded, had no clear notion of electrical potential, and absolutely wrong idea re-

12953 garding the indication of tension by electrostatic force. Many scientific professors and practical electricians and electrical engineers had, in 1880, scarcely clearer or more accurate notions than Werdermann in 1878, regarding electric potential or electro-motive force.

102 x-Q. Still it was known, was it not, prior to 1880, that to prevent great inequalities in pressure the size of the conductors should be as large as practicable?

A. Few people knew it. Every one thought of connections in series in which there is equality of current
12954 through the whole series, whatever be the size of the wire. Few people thought of connections in multiple arc. I know of no others than Lane-Fox and Edison who, prior to 1880, showed in any published paper or statement any knowledge of differences of pressure at different points of a multiple arc system.

103 x-Q. To what particular published statement of Edison do you refer in your last answer?

A. I know of no publication of Edison's prior to 1880 containing such statement as is referred to. In
12955 answering the question No. 102, I thought of, prior to August 9th, 1880, being the date of the application for the patent in the suit. I thought Edison's Patent 369,-280, applied for February 5th, 1880, contained indications that large conductors would be needed to prevent inconveniently great inequalities of pressure. On looking carefully through the specification of this patent I do not find any such indication in it, but I find in page 2, lines 112 to 114 of this patent (Defendant's Record, page 988), a clear indication of knowledge that
12956 there are differences of pressure between different points of a multiple arc system.

104 x-Q. It was known to others, was it not, prior to 1880, that in a given electric circuit the electric fall or drop is directly proportional to the specific resistances of the conductors, and inversely as their cross-sections?

A. Yes. When the same current travels through all the conductors in series, or when currents which are ascertained to be equal traverse through all the conductors, however the equality is maintained.

105 x-Q. Was it customary, prior to 1880, in some 12957
cases to employ mechanical generators of electricity, instead of batteries, for supplying current for electro-deposition vats; such, for instance, as described in the Napier publication referred to?

Objected to as not directed to any specific structure referred to on the direct.

A. I believe that Wilde's machine was so applied.

106 x-Q. If, during the latter part of 1879, you had 12958
been consulted as to the possibility of using such a machine, in place of the batteries described in the Napier article, the machine to be operated, for instance, by water power, or at the mouth of a coal pit, located a quarter of a mile from the deposition vats, would you, as an electrician or electrical engineer, have advised, in view of what was then known regarding these matters, that it could be done?

Objected to as merely hypothetical, as not 12959
referring to any structure mentioned on the direct, or in the evidence so far as appears. If there is any such structure in the case, defendant's counsel is asked to refer the witness directly to it. Further objected to as incompetent, asking an expression of opinion on a supposititious and only partially stated case.

Counsel for defendant replies, that the question is a perfectly proper one, the witness having during his direct examination undertaken to dis- 12960
cuss the Napier publication and its relation to the state of the art. And the counsel further states that he does not consider that he is under any obligation to refer to any specific structure, which may or may not be in the case.

A. I would have advised that it could be done by a magneto machine or Wilde or Gramme; but that it could not be done without very great loss of energy, or loss by interest on the value of the conductors, between

12961 the machine and the electro-plating establishment, unless a considerable number of electro-plating bars were placed in series. The plain arrangement of a single bath, with currents in parallel, through all the objects represented in Napier's diagram, would be extremely wasteful, if the source, whether battery or magneto machine, is at any considerable distance.

107 x-Q. Supposing there were a very large number of baths, would it still be a wasteful proceeding?

12962 Same objections as to last question.

A. It would be more and more wasteful, the greater the number of the baths, if they were connected in multiple arc; less and less wasteful, the greater the number, when they are connected in series.

108 x-Q. The wastefulness would depend upon the size of the conductor, leading from the machine to the bath, in any given case, would it not?

12963 Same objections as to previous question.

A. Yes. For definitely prescribed conditions, as to quantity of electro-plating to be done, the time during which it has to be done, and the cost of power at the source. There would be a certain size of the conductors, which would minimize the waste.

109 x-Q. How would you, as an electrical engineer, have then determined the proper size of the conductors to be used?

12964 Same objections as to last question.

A. If I was asked as an engineer to advise, and if I consented to do so, I would calculate according to my knowledge of the mechanical and electrical apparatus concerned, and my judgment on the whole case in respect to economy.

110 x-Q. If these calculations showed, that in the given instance the greatest economy permitted a loss of, say 25 per cent. of the total electric energy generated, and you were also desired to apply very nearly the same

pressure at the terminals of the baths, where would 12965
you have located that loss?

Same objections as to previous questions.

A. It would locate itself in the conductors, between the bath or baths and the source. There could not with any practical arrangement, or any arrangement such as that shown in Napier's diagram, be any appreciable difference of tension, on the different objects in one bath, unless resistances are introduced between
some of the objects and the bar on which they are 12966
hung, which may be done to give a different character to the metallic deposits on some of the objects from those on others.

111 x-Q. If, in constructing your house plant, your laboratory and lecture room had chanced to be located in a direction diametrically opposite the engine-room from that occupied by the house, how would you have constructed the plant?

Objected to as immaterial and hypothetical 12967
and not directed to the specific structure described in the direct.

A. I would not have lighted the lecture room at all. I only did so because I found I could do it by branch wires, brought away conveniently from the wires leading to the house. The wiring in the laboratory is for experimental purposes entirely, and conductors from the dynamo are brought into it for such purposes, and for
controlling and regulating the current and potential of 12968
the dynamo itself, which is only separated from the laboratory by a partition, with large openings for making any desired connection, the engine-room being practically a part of the laboratory.

112 x-Q. If you had not cared to have any lights in the laboratory and lecture room at all, but only in the house, what differences would you have made in the construction of the plant?

Same objection as to last question.

12969 A. I don't know. I certainly never would have made the plant at all, at that time, but for my experimental work on the Faure battery, in my laboratory. I might have made a smaller plant afterwards, to aid me in experimenting upon and in designing my electrical measuring instruments, but it is very improbable I should have made it of sufficient capacity for the lighting of my house.

113 x-Q. Assuming, however, that for some reason you had desired to light the house in essentially the same
12970 manner that you did, and that you did not care to use lights in the laboratory or lecture room, what other changes than the omission of the laboratory and lecture room lights would you have made?

Same objections as to last question.

A. I would have placed the engine and dynamo and secondary battery close to the house.

114 x-Q. But if, for any reason, it had still been more
12971 desirable or convenient to locate the engine and dynamo and secondary battery where they are now, then what changes other than indicated in cross-question 113 would you have made?

Same objection as to last question.

A. I would not have done the thing at all, in such circumstances, unless I was to use the engine and dynamo in the laboratory.

12972 115 x-Q. Assuming, however, that the circumstances had been such that they would have induced you to so light your house, and so locate the engine and dynamo, regardless of the laboratory and lecture room lights, then how would you answer the last question?

Same objections as above, and also, as the witness has stated that such assumption is contrary to the fact, and contrary to what he would have done.

A. If I had undertaken to do such a thing, as a responsible engineer I should certainly have examined all

Edison's patents and Lane-Fox's patents published up 12973
to that time, and any other published information that I could find, and I should have acted according to my judgment, thus informed.

116 x-Q. Leaving, for the present, out of consideration any patents which you did not at that time know of or were not familiar with, what other changes would you have made other than the omission of the laboratory and lecture-room lights?

Same objections as to last question. 12974

A. I don't know.

117 x-Q. Do you think you would have made any changes?

Same objection as to last question.

A. I really can't answer such a hypothetical question. I felt I was working altogether on Edison's system, differing essentially, as it did, from Swan's ideas or
designs at that time in respect to the arrangement of 12975
the lamps. I had both Swan and Edison lamps, kindly presented to me by the two inventors. I arranged all the Swan lamps in pairs of two, in separate series. This was as near as I could to the multiple arc of single lamps which, until I knew of Lane-Fox's patent, I thought was wholly of Edison's origination, but which, with the difference of earth returns instead of two insulated conductors, I found had been proposed by Lane-Fox in his earlier patent. I should most prob-
ably have arranged the system wholly for single Edison 12976
lamps of 100 volts in parallel instead of making up 84 or 86 volts by pairs of lamps in some cases and single incandescent lamps made later by Swan in other cases.

118 x-Q. Is this the only change that you can think of?

Same objections, and counsel protests against such examination, and witness being asked to carry his mind ten years back and state what he might have done in a hypothetical case.

21977 A. I would have looked into the whole question of the gauges of the conductors, the mode of insulating them and the shortest path to the house available. I have no doubt I would have made great changes in such matters, but it is impossible for me to tell now what they would have been.

119 x-Q. Assuming that you then knew what you now know to have been published relating to such matters prior to 1880, do you see any reason why you should have made any change in the system of con-
12978 ductors?

Same objection and protest by complainant's counsel.

A. I most probably would have made very considerable changes.

120 x-Q. In what directions?

Same objection and protest, also as the wit-
12979 ness has a number of times answered this question as fully as he states he can.

A. Gauge and character of the conductors, mode of insulation and place of laying them.

121 x-Q. Would you have made the conductors leading to the house larger, or would you have so modified the conductors leading to the house that the drop in tension thereon should vary practically the candle-power of the lamps in the house?

12980 Same objections and protest, and the witness is instructed by complainant's counsel that he is not compelled to guess or speculate as to what he might or could or would have done under hypothetical circumstances ten years ago, nor to state further than his positive knowledge in answer to such question.

A. I should certainly have got them considerably shorter, and I believe much more massive, so as to entirely escape all practical inconvenience from difference

of pressure between the house and the dynamo ter- 12981
minals.

122 x-Q. Would the making of the conductors more massive cause the drop in tension thereon to vary practically the relative candle-power of the lamps?

Same objection as above.

A. No. It could not vary the relative power of the lamps, but it would bring the pressure in the house to
be so nearly the same as the pressure at the dynamo 12982
terminals that the engine-man would have to regulate simply to make the proper potential at his own volt-meter, irrespectively of his observation of the strength of the current going to the house, or of any message from the house by telephone or otherwise, as to the pressure shown on the volt-meter there. This convenience would be quite worth the cost of the heavier metal in the conductors.

123 x-Q. What led you to select the particular size
of conductor which you did use from the laboratory to 12983
the house?

A. Merely economy of power and copper, irrespectively of the inconvenience of drop of tension in the conductors.

124 x-Q. Assuming that at the time you constructed this installation you had also wished to light another house similar to your own, but located in the opposite direction with respect to the engine room, and at approximately the same distance, do you not now think
that you would have practically duplicated the system, 12984
except for the laboratory and lecture-room lights?

Same objections, as hypothetical and immaterial and asking the witness to speculate, as have been made to previous questions.

A. I shall be glad, if consulted professionally by the defendant, to give them the best engineering advice I can as to what ought, in my opinion, to be done in such a case. It certainly ought not to be merely to dupli-

12985 cate my present arrangement with the same gauge of conductors.

125 x-Q. The question was intended merely to ask you if, with the knowledge that you then had, you do not now think you would have practically duplicated the system so far as the arrangement of conductors is concerned.

The same objections as to last question, also as clearly incompetent to ask the witness what
12986 he now thinks he might then have done in a case which did not occur.

A. I think I can tell very clearly now, on consideration, what I should then have done. I was then exceedingly anxious to keep the potential in the house, always within, at the most, one or two volts of constancy. I should therefore have placed either an automatic regulator in each house and made the conductors perhaps not larger than the present; or I should have made the
12987 conductors so large that in all ordinary use in either house the pressure would have been within two volts of what it is at the dynamo terminals. I should probably have adopted the latter alternative, because I should certainly have found the regulation required for the former considerably more expensive than the extra metal required in the conductor for the latter.

126 x-Q. If in the latter part of the year 1879 a friend had come to you for advice, stating that he had a house in which to place 500 incandescent electric lamps, all of
12988 the same general character, and had asked you how he should proceed, how would you, as an electrical engineer with the knowledge and information then accessible, have advised him?

Same objection as to last question.

A. I should certainly have advised him against any such arrangement, as no incandescent light was known at that time which could possibly have given him a satactory isfresult.

127 x-Q. Assuming that such an incandescent lamp 12989
did exist at that time, then how would you have advised him?

Same objections as to last question.

A. I should almost certainly have advised him, what we now know as the tree-main system.

128 x-Q. Why?

Same objection as to last question. 12990

A. Because that is the system that would give the best results. Mr. Swan's multiple-series system, if each lamp had only been adapted for 20 or 30 volts, might have been thought of, but I should have preferred independent bridges of four or five lamps, to bring up the pressure to 80 or 100 volts independently for each such row of lights.

129 x-Q. Supposing the lamps had required a difference of potential of 100 volts each? 12991

Same objections as to last question.

A. I would probably have advised the same plan as that which I afterwards used in my own house.

130 x-Q. Supposing that he had asked you where he must place his generator, what would have been your advice?

Same objections as to last question. 12992

A. With the lamps known in 1879, I could not have given him any other advice than that which I pointed to in my evidence before the Parliamentary Commission of 1879. The possibility of an incandescent light of more than five or ten volts was not then known, I believe, to any one in the commission, or who gave evidence before the commission, and it certainly was not known by any published document, I believe, except Lane-Fox's 1878 patent, which suggested the possibility of an incandescent light of 100 volts, though

12993 it did not show how to realize it successfully in practice.

131 x-Q. Assuming, however, that the incandescent lamp, such as referred to in cross-question 129, had existed and was known to you at that time, how would you have advised him about placing the dynamo?

Same objections as to previous question.

A. I cannot assume this knowledge without other
12994 knowledge that became public also between 1878 and 1881.

132 x-Q. Why not?

Same objections as above.

A. Because I cannot assume a reversal of the history of science, a displacement of the order of discovery and of the formation of ideas founded on discoveries in science.

133 x-Q. What are the other ideas so closely linked
12995 to the assumption of the existence of the incandescent lamp referred to that you cannot make the assumption called for in cross-question 131?

Same objections.

A. The horse-power required to produce a certain quantity of light, by any of the lamps known in 1878, was foreknown by no human being as to be invented between 1878 and 1881. A suitable dynamo for excit-
12996 ing the unknown, not then invented lamp. The dislodging of one's own mind from the idea of series for lamps, towards which Khotinsky's patent and a reversal of Werdermann's combination gave the only published suggestion, except Lane-Fox's 1878 patent.

134 x-Q. If in the latter part of 1879 or early part of 1880 your friend had said: "I have 500 incandescent electric lamps, each requiring 100 volts, arranged in multiple arc, in my house, and I have a dynamo supplying these lights which is located within the house, but I do not like the

noise which it makes and wish to have it moved 12997
elsewhere; I have a water-power located a quarter of a mile from the house, and I wish to have you advise me whether I can place this dynamo or another one, at the water-power, and supply my lights from it." In such case how would you have advised him at that date, in view of what was published?

The same objection as to previous questions.

A. It is quite certain that no such combination as you 12998
describe existed at that date, unless possibly it had been realized by Edison himself.

135 x-Q. The question merely makes the assumption and asks you under that assumption, what you would have advised?

Same objection, and the complainant's counsel draws the attention of the Court to this continued hypothetical examination as improper.
It is only allowed by complainant's counsel be- 12999
cause the circumstances under which the evidence is taken preclude an appeal to the Court as to whether such questions should be permitted.

Counsel for defendant replies that he has no desire to protract the examination; on the contrary is anxious to complete the examination as soon as possible; that the witness having testified upon direct examination regarding the state
of the art in 1879, and particularly so in his 13000
answer to question 8, as well as elsewhere, it is believed to be perfectly proper that he be required to now express his views fully as to all matters pertaining thereto.

A. I would probably have advised altering the arrangement to multiple-series, and using a Brush dynamo to give a potential of six or seven hundred volts. This was the plan which I saw in use on board H. M. S. "Inflexible," in 1881, with 40 or 45 volt Swan lamps.

13001 The dynamo used was a Brush dynamo, on board the ship, and if it had been a house to be lighted from a distance of a quarter of a mile, the multiple-series arrangement and the high voltage dynamo would have been more decidedly the right thing, so far as any idea I had myself formed, prior to 1881, went.

136 x-Q. Why?

Same objection.

13002 A. To avoid loss of energy in the conductors.

137 x-Q. But supposing that your friend had said, "I do not wish to have a current of pressure of more than 100 volts in my house?"

Same objection.

A. That is an idea of altogether a later date. There was 700 volts all through the "Inflexible." In the officers' cabins and every part of the ship.

138 x-Q. I think you did not fully answer my question.
13003 Assume that the friend who asked your advice, as above supposed, did not wish to have more than 100 volts pressure in his house, how then would you have advised him?

Same objections as above.

A. To wait for a year or two till we could get a proper dynamo, and till we knew something more of incandescent lamps. The first dynamo on this side of
13004 the Atlantic that could have possibly fulfilled the supposed conditions was made for myself by Siemens after I had seen the "Inflexible" installation in the summer of 1881. It was supplied to me in the December of that year. The only dynamo I possessed before that, and whose qualities I knew, except the Brush, as it had been seen in the Glasgow Gas Exhibition, and as I had seen it on board the "Inflexible," was a series-dynamo supplied to me by Siemens in the spring of 1881, and Gramme dynamos, which were then all made on the series system. None of these dynamos, except

the Brush, would have been suitable for electric lighting with incandescent lamps. 13005

139 x-Q. Assume now, for the purposes of this question, that a proper dynamo was to be had in the latter part of the year 1879, or the early part of the year 1880, and please answer the question with this assumption.

Same objection; also, as it has been distinctly stated, that there was no such dynamo, and the assumption required is therefore contrary to the 13006
facts as proved, and not permissible, even in a hypothetical question.

A. I cannot answer a question founded on an unreal and impossible assumption. The supposition that inventions essential to the question had been made, which had not been made, and that ideas which grew up during several years subsequent to the making of these inventions, through large experience in their use, had been formed in the mind of an imaginary friend 13007
asking for advice in the early part of 1880.

140 x-Q. When was an electric generator, such as contemplated by interrogatory 10, first publicly known?

A. The nearest approach to it I know of is that described in Mr. Upton's paper, published in "Scribner's Monthly," in February, 1880, with a prefatory note from Mr. Edison, and found in defendant's record, page 895.

141 x-Q. When were incandescent electric lamps, such as contemplated by interrogatory 10, first publicly 13008
known?

A. So far as I know this same paper was the first to make them publicly known. They certainly were not generally known in England, to the best engineers and electricians, at the time of the Parliamentary Commission of 1879.

142 x-Q. Were you aware of the contents of this paper, published in "Scribner's Monthly," when you gave your answers yesterday to cross-questions 131 and 139?

13009 A. I did not remember the individual article; I have had it in my house for years. Since I came into this room this morning I have looked into it, in the defendants' record, and it perfectly confirms all my recollections on which my answers of yesterday were founded.

143 x-Q. How do you mean that it confirms your recollections upon which you founded your answers of yesterday?

A. That in the beginning of 1880, neither dynamo
13010 nor electric lamp fulfilling the conditions presented in some of the questions had been made known by any publication.

144 x-Q. How does this paper in "Scribner's" prove to you that neither the dynamo nor the electric lamp had not been made known in some other publications before that day?

A. It contains no reference to any such previous publication.

145 x-Q. And from that fact simply do you wish to
13011 be understood as saying that it proves that no publications of such devices were made before that time?

> Objected to as not correctly quoting the witness, whose statement was that the paper "confirmed his recollection."

A. No.

146 x-Q. Then there may have been other publications, describing either lamps or dynamos or both,
13012 which were suitable for the conditions required by interrogatory 10 prior to this Scribner article, may there not?

> Objected to, as not limited to the witness's own knowledge.

A. I know of none.

147 x-Q. Is the dynamo described in this Scribner article suitable for operating incandescent lamps arranged in multiple arc?

A. Yes; for operating about fifty lamps. I recog- 13013
nize it by its appearance in the drawing, which agrees with an Edison dynamo shown to me by Messrs. Anderson & Munro in Glasgow a year or two after the date of the Scribner article. In the Scribner article, under the diagram showing the dynamo, there appears as its designation, "Faradic Generator," and it is stated in the text that Mr. Edison proposed to so call it after Faraday.

148 x-Q. Supposing that in the earlier part of 1880,
or the latter part of 1879, you had been told of the 13014
existence of such a dynamo as this, and of such incandescent electric lamps as called for by interrogatory 10, how then would you have answered the question put in cross-question 134?

> Same objections as to cross-question 134, and also as requiring a supposition contrary to fact, as there was no plant of 500 incandescent lamps in existence at the period referred to.

A. I would have said you would need eight or ten 13015
such dynamos, unless we find we can get larger dynamos of the same kind, so that a smaller number, or even one dynamo may suffice; and you must put plenty of copper into your conductors between your water-power station and your house.

149 x-Q. How would you, as an electrical engineer, have determined the proper size of wire to use between the water-power station and the house?

> Same objections as to last question. 13016

A. I would have made it such that, when all the lights are burning in the house, all will be satisfactorily bright, and that when only one or two or three are burning they will not be damagingly over-incandesced.

150 x-Q. You would not, would you, have taken into consideration the cost of the conductor?

> Same objections as to the last question.

13017 A. I should certainly have taken it into consideration, fundamentally.

151 x-Q. What part would it have played in your calculations?

Same objection as to last question.

A. I would have calculated the amount of copper required to attain the object, and considered whatever expenditure might have been found required for it to
13018 be necessary as a part of the prime cost of an installation which could be satisfactory.

152 x-Q. What considerations would have entered into the problem?

Same objections as to last question.

A. First, the difference of voltage on the lamps allowable in order to fulfill the conditions I have stated in answer to cross-question 149.

13019 153 x-Q. Is that the only consideration that would have governed you?

Same objections as above.

A. That is the consideration on which I would have founded the quantity of metal required. I should probably have chosen copper.

154 x-Q. You have not quite answered my question, which asked if that would have been the *only* consid-
13020 eration?

Same objections as above.

A. Yes, the only consideration. I should have thought of the possibility of regulating, and I am perfectly certain I should then have judged what I should judge now, that it would be much better to go to the expense, once for all, of putting in plenty of copper than to keep a man always regulating either in the house or at the dynamo. I know well what an intolerable idea it is, quite irrespectively of the ques-

tion of cost, to any country gentleman or wealthy 13021
man, to be obliged to have somebody always on watch, night and day, unless it is some person doing actual work, such as stoking a fire or tending an engine, and even that, unless in a ship, or in a factory arranged for night and day work, is an idea which I believe would take away three-fourths of the satisfaction of having the electric light in one's house from any one capable of appreciating truly this pleasure.

155 x-Q. If however, owing to the cost of the copper, your friend should have preferred to put up with 13022
the inconvenience of having some one to attend to the regulation, would you have then advised him that he could have thereby saved in the expenditure for copper?

Same objections as above.

A. I probably would have suggested to him that a man costs £1,000, and that two men, for four hours off and for four hours on, would cost £2,000, and that he 13023
had better put his money, which would be vastly less than that, in copper.

156 x-Q. I fear you do not fully understand the question. Would you, as an electrical engineer, have told him that he could use less copper, and thus save in the original outlay?

Same objection as to previous question.

A. I quite understood the question. Of course he 13024
would have saved in the outlay in copper, but he would have to spend more otherwise to get good results, irrespectively of the question of feeling, as to the extreme painfulness of the idea of keeping any person always on the watch, night and day, unless in a business establishment.

157 x-Q. Where else would he "have to spend more?"

Same objections as above.

13025 A. In wages.

158 x-Q. Is that all?

Same objections as above.

A. Yes.

159 x-Q. Would the loss due to transmission of electricity from the water-power station to the house have remained the same?

13026 Same objections as above.

A. There would have been considerably more loss, which would be an expense of quite a serious character, if steam power or a gas engine was employed, but I considered the water power in the question to be abundant, in my answer, and did not take it into account when I said only wages.

160 x-Q. Would this increased loss of electricity, due to the smaller conductors, produce any variation in
13027 the relative candle-power of the lamps, in the house?

Same objections.

A. None whatever. We are supposing the pressure where the mains enter the house to be kept constant, or say within five per cent. of absolute uniformity.

* * * * * *

246 x-Q. If in the early part of the year 1880 you, as an electrical engineer, had been shown such a system
13028 as "Defendant's Exhibit Thomson No. 5," and had been asked how to construct the conductors leading from the source to the consumption circuit, provided the source was distant, say from one-quarter to one-half a mile, how would you have proceeded?

Objected to as hypothetical, as the witness is not compelled or required to speculate as to what he might, could, or would have done more than ten years ago, and cannot put himself in a position to fairly make any such statement;

also as the diagram "Defendant's Exhibit Thom- 13029
son No. 5," is a mere sketch, containing no details which will fairly enable the witness to testify with full knowledge in regard to it. Witness is requested to demand every detail connected with the problem suggested.

A. There was no knowledge among engineers and electricians of that time to allow any one to give a plan for a system such as that shown in the diagram, with the source one-quarter of a mile from one end, and a 13030
mile and three-quarters from the other end of a row of lamps connected in parallels.

247 x-Q. I presume in giving your last answer you have reckoned the consumption-circuit as a mile and three-quarters long, by calculating the relative distances shown in the diagram. Assume that the consumption-circuit is of the character set forth in your answer to x-Q. 245, and that the source was simply to be moved away from that consumption-circuit?

Same objection and instruction as after last 13031
question.

A. My answer is the same as that which I gave to x-Q. 246, with the omission of all after the word "diagram;" and the explanation that incandescent lamps and dynamos proper to feed them and the strengths of current through them in ordinary use, and the strength of current that they will bear without breaking and the variations of strength permissible without inconven- 13032
iently great variation of the light, were not sufficiently known at that time to allow any engineer in the world to give trustworthy advice on the subject imagined in the question.

248 x-Q. Would you have made the size of the conductors dependent upon the cost of copper and of producing electricity?

Same objections and instructions as above.

A. Yes, and on a vast number of other considerations

13033 of properties of matter and possibilities of electric lighting not known to any living man at that time.

Recess until 2:45.

249 x-Q. Would you, in the early part of 1880, have made the size of the conductors, in the instance supposed in the last two questions, such that there would have been greater drop per unit of length than in the consumption circuit?

13034 Same objections and instructions.

A. I can't tell what I should have done in such a matter in 1880.

250 x-Q. What do you think you would have done?

Same objections as above.

A. I have not the slightest conception.

251 x-Q. You, as an electrical engineer, knew at that
13035 time, did you not, that it would be desirable that the consumption circuit should be constructed of sufficiently large conductors to obtain an approximately even distribution of potential throughout?

A. No, on the contrary, engineers of that time, and myself among them, thought only of lamps in series for consumption circuits.

252 x-Q. Was that true of Lane-Fox?

A. I have already excepted Lane-Fox and Edison in a previous answer.

13036 253 x-Q. Then, if you were familiar with Lane-Fox's publications at that time, you would have known the matter set forth in the 251st x-Q., would you not?

A. At that time there was nothing to prove any practical value in what Lane-Fox had published; and nothing was known of the possibility of a practical, useful incandescent lamp.

254 x-Q. But you, as an electrical engineer, knowing of the publications of Lane-Fox, would have known, would you not, that, in order to obtain an even distribution of potential through a consumption circuit having

translating devices connected in parallel or multiple 13037
arc, the conductors constituting the consumption circuit should be sufficiently large?

A. It needed no knowledge of the publications of Lane-Fox to know that for the objects stated in the question the conductors must be sufficiently large.

255 x-Q. And you knew also that if those translating devices were incandescent lamps of the character described in the "Scribner Magazine" article of February, 1880, that it would be desirable, when they were
connected in multiple arc in a consumption circuit, it 13038
should have an approximately even distribution of potential throughout?

A. There were no means available, to myself or any one else at that time, to give any practical answer to the question how nearly uniform must the potential be, and what are the best practical means of attaining to the requisite uniformity.

256 x-Q. Your knowledge of the operation of electric lamps of other kinds, and of electric translating devices
generally, would naturally have led you to suppose, 13039
would it not, that these incandescent lamps would operate best when supplied with an approximately even distribution of potential.

Objected to as hypothetical; the witness should be questioned as to facts and not suppositions.

A. I had never seen any such lamp, and I had no
information that could guide me as to the limits of 13040
variation of potential, conveniently allowable in its use.

257 x-Q. Do you wish to have the Court understand that if in the early part of 1880 you had been asked whether such lamps as those described in the Scribner article, for instance, would operate best when subjected to approximately the same difference of potential throughout the consumption-circuit, you could not have expressed any opinion on the matter?

Objected to as hypothetical, asking the wit-

13041 ness to speculate, and as without foundation, unless it is shown that such a question was asked the witness and answered by him in 1880.

A. I am perfectly satisfied that the Court will not misunderstand any answer I have given.

258 x-Q. Question repeated?

Same objection, also objected to as fully answered by the witness, in so far as it is proper
13042 to answer any such question, and the witness is instructed that, if he has answered such question as far as he can, he is at liberty to so state and not compelled to answer differently simply because a question is repeated.

A. No.

259 x-Q. What opinion would you then have entertained?

13043 Same objection as to previous question.

A. I utterly object to any such question being put. I feel sure that no court in the United States could possibly expect me now to give an imaginary answer to a question put to me in 1880, on the supposition that I then knew just exactly what it was possible I could have known by having read every patent, practical or unpractical, or every newspaper report, or magazine article shadowing forth some new, possibly
13044 to be, practical invention in electric lighting. If I am wrong in making this protest, I apologize to the Court, and say that it is in ignorance of the rules and usages of the United States courts that I do so.

Complainant's counsel states that the matter of the above protest by witness is covered by counsel's objections to such questions, and that if the testimony were being taken within the reach of a United States Judge the testimony would be brought before such Judge, and

no such supposititious questions as are being 13045
asked would be answered, unless upon distinct order of the Court. As the matter stands, counsel can only instruct the witness that he is not bound to guess, speculate, suppose and endeavor to carry his mind back eleven years and imagine what he might have stated in answer to questions which were not proposed to nor answered by him at that time, and complainant's counsel further instructs the witness that he is at liberty to say he cannot answer such ques- 13046
tions, if such be the fact.

Counsel for defendant desires to state that it is far from his purpose or desire to ask the witness any unnecessary or improper question, and, that he may fairly present his reasons for asking the line of questions now objected to, desires to direct attention to the fact that witness was asked in question 4 of the direct examination whether, in and prior to the year 1880, he was familiar with the science of electric lighting in 13047
Great Britain, to which he replied in the affirmative; the witness further stated in the latter part of his answer to question 4, while referring to the Parliamentary Commission of the 28th March, 1879, that he made a study of the whole subject up to that period and learned of the most recent proposals for electric lighting by the most able engineers. In Q. 12 the witness is virtually asked to carry his mind back to the year 1880, and consider whether the conception 13048
and carrying into practice of the system of distribution described in the 10th interrogatory was "one which would naturally have suggested itself to a person skilled in the art and familiar with the theory and practice of electricity at that day, or was within the ordinary skill of the calling of electricians at that date, if he or they had been required to devise or construct" a certain system. It is thought, therefore, that the present question calls for nothing which is not per-

13049 fectly consistent with the line of the direct examination. In his answer to Q. 12 the witness expresses his opinion that, in and during the year 1880, the system of distribution referred to in the 10th interrogatory would not have suggested itself to a person skilled in the art and familiar with the theory and practice of electricity at that day, and counsel for defendant now desires to investigate the reasons for this belief.

13050 Complainants' counsel objects to as improper, and moves to strike from the record, the above argument of the defendants' counsel as directed to persuading the witness to answer the prior question objected to.

260 x-Q. Please state whether, in your opinion, the
placing of lamps such as described in the Scribner
article of February, 1880, in parallel, would have natur-
ally suggested itself to a person skilled in the art dur-
13051 ing the early part of the year 1880?

A. It might or might not. It might, as is proved by Lane Fox's previous patent. It might not, as is proved by the fact that notwithstanding the publication of Lane-Fox's patent, and of the patents which were applied for by Edison in 1880, as late as 1881 the system of multiple-series was adopted for the lighting of H. M. S. "Inflexible" in 1881.

* * * * * *

264 x-Q. Please state whether, in your opinion, the
13052 desirability of thus saving copper in the two conductors
leading from the source to the consumption circuit,
even though it might cause a loss of 10 or 15 or more
per cent. of potential, would have naturally suggested
itself to a person skilled in the art and familiar with
the theory and practice of electricity in the early part
of the year 1880?

A. It might have done so, if he had not known the qualities of incandescent lamps. When these became somewhat known in the course of the next and two or three following years, any such drop in potential

seemed fatal to most people, so much so, that 13053
even Sir William Siemens, several years after 1880, and
Mr. Crompton also, and I believe almost all engineers
in this country thought it impracticable to carry out a
system of electric lighting through any larger district
than would allow nearly enough uniform voltage to be
maintained throughout it for the good working of the
lamps without intolerably heavy expenditure of copper.

* * * * * *

293 x-Q. The economy with which incandescent
lamps may be operated has increased materially, has it 13054
not, during the last five or six years, owing to the
greater efficiency of the lamps manufactured?

A. Yes; very much, I believe.

* * * * * *

RE-DIRECT EXAMINATION OF SIR WILLIAM THOMSON BY SAMUEL R. BETTS, ESQ.:

332 Re-d. Q. In cross-questions 148 to 160 a hypo- 13055
thetical case has been put before you, involving a number of suppositions, stated in the questions, and you have been asked what you would have advised in the latter part of 1879, or earlier part of 1880, if such a problem as is set forth in these questions, had been then put before you for solution. I now desire to ask you

(1) Whether any case involving the suppositions of
these questions was, in fact, presented to you in 1879 or
1880 for your opinion thereon? 13056

(2) Whether, to your knowledge, the supposititious problem set forth in these questions had ever been stated in substantially the same way it is therein stated, for solution by any one, prior to the date of application for the Edison patent in suit?

(3) In what respects, if any, do the suppositions contained in these questions differ from the actual condition of the art of electric lighting as it existed at the time referred to?

(4) Whether, in answering these questions, you have

13057 intended now to state what you would in fact have then advised, in view of the actual condition of the electric lighting art at that time, and independently of the suppositions contained in the questions?

(5) Whether or not, in your opinion, the suppositions of these questions, and the manner of stating the problem proposed therein, would in any way point out the difficulties and aid their solution, and do this in a different manner from any suggestion which has been made in 1879 or the earlier part of 1880?

13058 (6) Whether or not there is in the suppositions and suggestions of these questions, and in the answers called out by them, anything more than, or beyond, what would naturally have suggested itself to a person skilled in the art, and who had only the information which existed therein in 1879 and in the earlier part of 1880?

Objected to as immaterial, and clause 4 is objected to as endeavoring to elicit from the wit-
13059 ness a different answer, since the questions and answers fully explain themselves.

A. No case involving the suppositions stated in x-Qs. 148 to 160 was, in fact, ever presented to me in 1879 or 1880 for my opinion, nor put before me, or known to. me, by any publication, or communication from any person.

The supposititious problem set forth in those questions had never been stated substantially in the same
13060 way as therein stated, for solution by any one, prior to the date of application for the Edison patent in suit, so far as I know.

No house was wired for electric light at that time. No incandescent lamps existed which could be expected to light the house of my imaginary friend of Q. 134. The "Scribner" article referred to contained no evidence of lamps having been made, or of its being likely that lamps would soon be made, which would last well enough, or be in any respect practically available for the lighting of the supposed house by "500 in-

candescent lamps." Nothing of the kind was known in 13061
Europe until after the end of 1880. No dynamo or set of dynamos working together, which could fulfill the conditions supposed to be put before me by my friend, "in the latter part of 1879 or the early part of 1880," were then known to be possible. The dynamo represented in "Scribner's Magazine" was not known to have been realized outside Edison's laboratory and workshop. From the appearance of the armature as represented in the picture, and its dimensions as com-
pared with the picture of Mr. Edison standing beside it, 13062
any electrician could now judge that it was not capable of supplying more than fifty or one hundred 100-volt lamps. From knowledge generally possessed at that time it could not have been told that five or ten such dynamos could work in parallel. On the contrary, judging from the only general experience of that time, which was that of series-wound dynamos, it might have been supposed that two or more dynamos could not work in parallel. Taking them separately and all to-
gether, the suppositions contained in x-Qs. 148 to 160, 13063
assume something wholly different from the actual condition of the art of electric lighting as it existed at the time referred to, and which was not found realized until after the end of 1880. Even the supposed objection of my friend to have more than 100 volts in his house was prophetically out of date in the latter part of 1879 or the early part of 1880. So far as I know the first indication of a limit to the voltage admissible into a house was given by myself in an address delivered on the 1st
September of 1881 to Section A of the British Associa- 13064
tion at its meeting at York in that year.

In answering the question referred to I could not say what I would, in fact, have then advised. I did say what, judging with my present knowledge, I thought I might possibly or probably have advised, not in view of the actual condition of the electric lighting art at that time alone, but guided by the statement supposed to have been made to me as contained in the questions (x-Qs. 148 to 160).

The suppositions of these questions and the manner

13065 of stating the problem adopted in them point out difficulties and suggest modes of solution unknown and unthought of in 1879 or the earlier part of 1880. No one, in fact, at that time had diagnosed the problem of lighting a large country house in the manner put forward in the statement and suppositions until long after 1880.

* * * * * *

The idea suggested in the x-Qs. 150, 151, 152, 153, 154, 155, 159 and 160, that expense on copper might be advisedly avoided by reducing the
13066 supply conductors, notwithstanding that this would entail a more than negligible drop in the pressure, was not known in the early part of 1880, nor I believe to any one prior to the date of Edison's Patent No. 264,642; and so also was the idea unknown of regulating at a central station, so as to maintain a constant lower pressure at a distant point, whether with or without the aid of pressure wires.

* * * * * *

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UNITED STATES CIRCUIT COURT, 13069

District of New Jersey.

Edison Electric Lighting Company

vs.

Westinghouse, Church, Kerr & Co.

Stipulation as to Filing, &c., of Commission. 13070

It is hereby stipulated and agreed by and between counsel for complainants and counsel for defendants, representing the respective parties on the execution of this commission, in the City of Glasgow, that the deposition of Sir William Thomson, containing his testimony as written out and signed by him, and the entire commission as made up and certified by the United States
Consul, and sealed up and directed to the Clerk of the 13071
Court in which this suit is brought, by the commissioner, may be intrusted to the custody of Mr. William J. Jenks, as the agent of said commissioner, to be by him conveyed to the United States for filing, and that the said William J. Jenks shall retain this commission, until by order of court entered on agreement of counsel, or otherwise, he is directed what disposition to make of said commission, in order that the same may be opened and filed in this case.

It is hereby further stipulated between said counsel 13072
that all formalities and technicalities as to taking down, certifying, transmission, filing and opening of said commission, are hereby waived, except that it is to be transmitted as above stated in this stipulation.

Glasgow, January 21st, 1891.

Sam'l R. Betts,
Of Counsel for Complainant.
Charles A. Terry,
Of Counsel for Defendant.

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